Color Atlas of Dental Medicine

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Orthodontic Diagnosis

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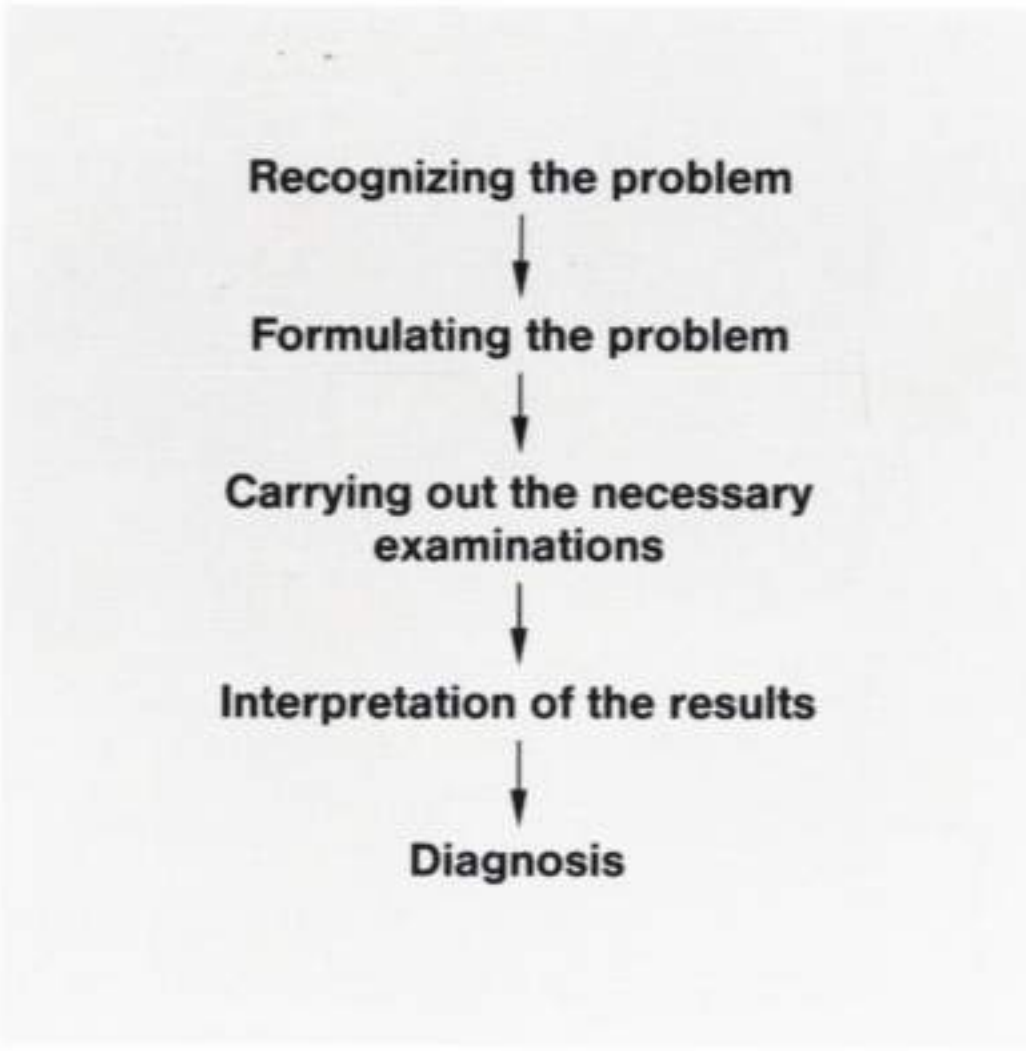
Relevance of Diagnosis

Diagnosis: The recognition and systematic designation of anomalies; the practical synthesis of the findings, permitting therapy to be planned and indication to be determined, thereby enabling the doctor to act.



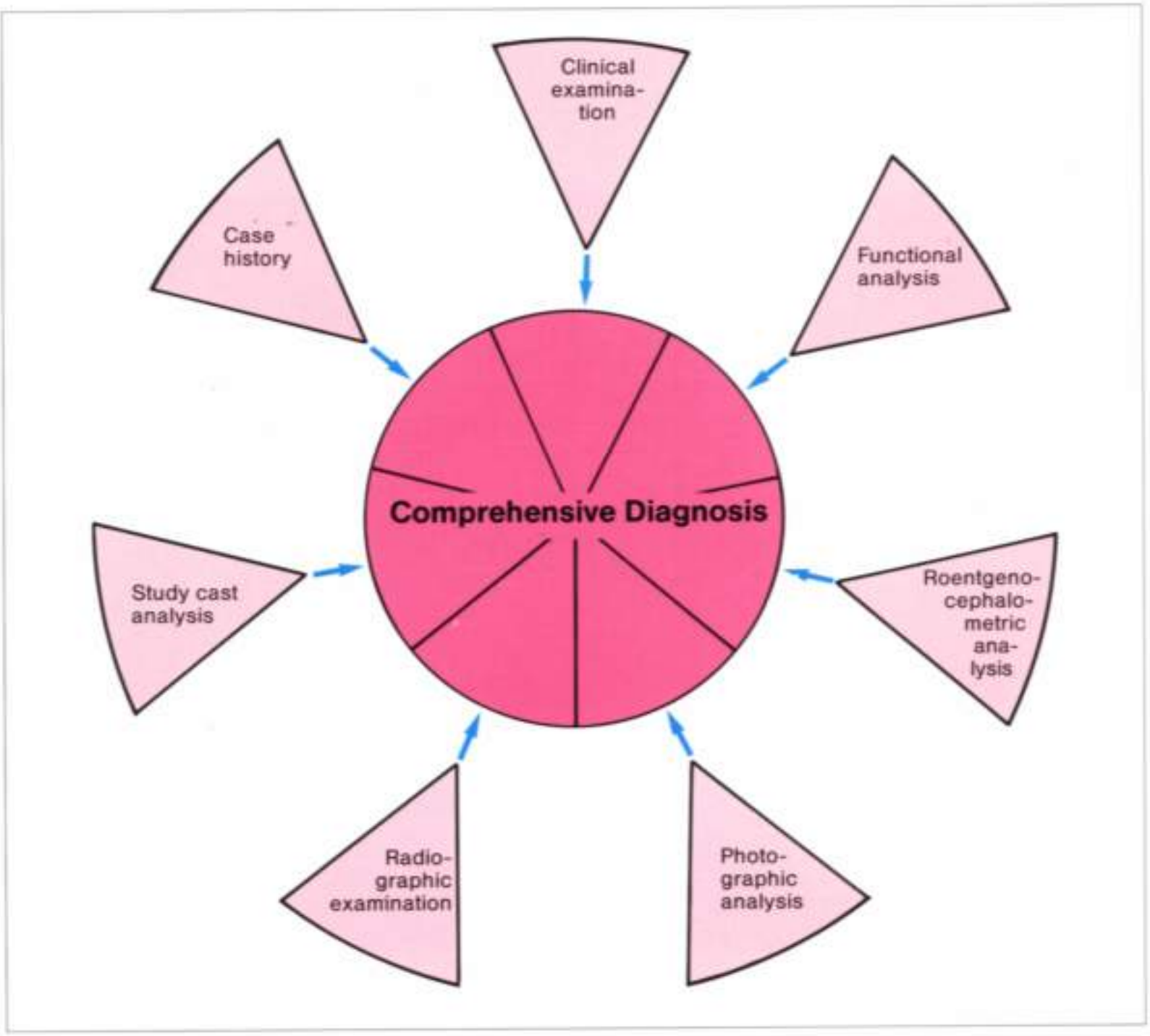
Numerous observations, individual findings and analyses, which allow a broad-based decision to be made for the particular patient, are a *prerequisite* for a correct diagnosis in orthodontics. The informations must be objective, relevant, and accurate. The diagnostic criteria should include the entire orofacial system, yet should also be selective. Certain *norms* are required for diagnostics, i.e. for the assessment of abnormalities of the stomatognathic system. Comparing to an ideal norm (e.g. eugnathia) or statistically determined mean values (e.g. Pont index) is unrealistic. Personal, individual norms do exist for each case which take into account the individual development of the masticatory system (the "individual optimum" according to Andresen, 1931). Analyzing the individual data systematically enables diagnosis to be carried out according to type. *Grouping* the cases together results in larger groups, so-called typical anomalies, which can be divided into further *classifications.* Atypical anomalies also exist, so-called borderline cases, which depend in their type and number on the respective methods of considering the case and its classification.

Comprehensive Diagnosis

Nowadays, orthodontic diagnosis should be routinely based on various methods of examination (Fig. 1). The synthesis of these various individual findings determines the orthodontic diagnosis. The individual results must be checked prior to evaluation to ensure that sufficient examinations have been carried out, and that the most relevant examinations were included, and not simply that an immense volume of data has been collected without having included the most relevant details.

The comprehensive diagnosis should be a summary of the most important facts and should not take insignificant secondary symptoms into account, as they are of no relevance to the treatment. The more experienced the orthodontist is, the quicker he or she will recognize the problem, select the appropriate examinations for the case, and make optimum use of it.

Certain discussions as to whether the etiological, clinical, functional, or radiographical aspects should be considered most important for the diagnosis are unwarranted. However, in some cases further examination methods may be required. For example, cinematographic or palatographic registrations should only be carried out in exceptional cases for a detailed investigation of specific problems.



1 Essential orthodontic examinations
The seven different analytical techniques are all of the same relevance for orthodontic diagnosis.

Prior to carrying out further examinations, the time and effort required should be compared to the possible therapeutic consequences.

Even in adult cases, where more elaborate diagnostic examinations are necessary, the time and effort required must be relative to the possible results.

Computer analysis has also been employed for orthodontic diagnostics over the past few years. The computer enables quick and accurate evaluation of the individual findings. It can correlate the various data and indicate a particular problem. However, the computer cannot make a diagnosis. The practitioner must still interpret and synthesize the data determined by electronic means and plan the therapy. The so-called computer diagnosis often includes a preprogrammed decision which usually leads to standardization of the treatment methods and results in stagnation in one's speciality.

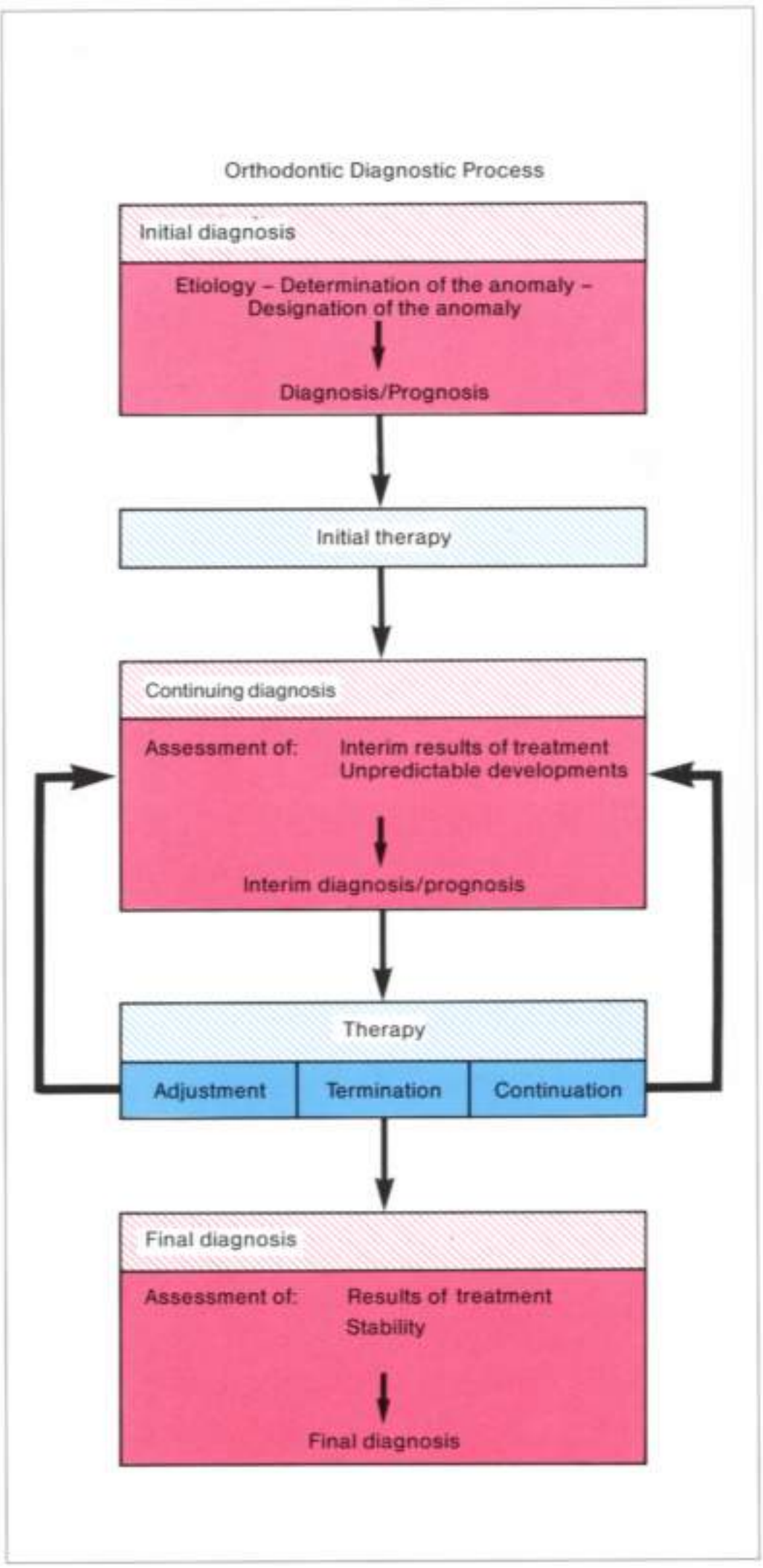
The causes of *incorrect diagnoses* are usually insufficient informations or prejudiced decisions made in order to adapt the case to a particular type of treatment.

Diagnostic Process

Orthodontic diagnosis can be referred to as a *diagnostic process* (Fig. 2).

The diagnostic procedure commences with the *initial examination,* during which a large number of individual findings and analyses of the etiology and particulars of the malocclusion are clarified by means of synthesis. The objective is to describe the morphological and functional characteristics of the case, using certain terms, and to provide a prognosis of the anomaly, i.e. a forecast about the future development of the deformity.

Due to possible unexpected developments and reactions during the course of treatment, this initial diagnosis must be reviewed regularly. While doing so, the various data obtained during the initial diagnosis must be checked selectively to ensure that they are still relevant. The objective of regular examinations is to reassess the initially defined therapeutic methods and to establish whether further procedures are necessary or whether the treatment plan should be changed. This is called *continuing diagnosis.* The main objective of the *final check-up* is to assess the stability of the treatment results.



2 Diagnostic process for orthodontics – general course of treatment

Once the initial diagnosis and probable prognosis have been established, the necessity for treatment and the plan of treatment are discussed at length with the patient. The degree of motivation and future compliance of the patient should be assessed and, when children are being treated, discussed with the parents.

At the beginning of the therapy the entire course of treatment – influenced by the growth processes – usually cannot be predicted exactly.

After each phase of treatment, the clinican must check that the therapy is correct, thus, if necessary, enabling the course of treatment to be adjusted in good time.

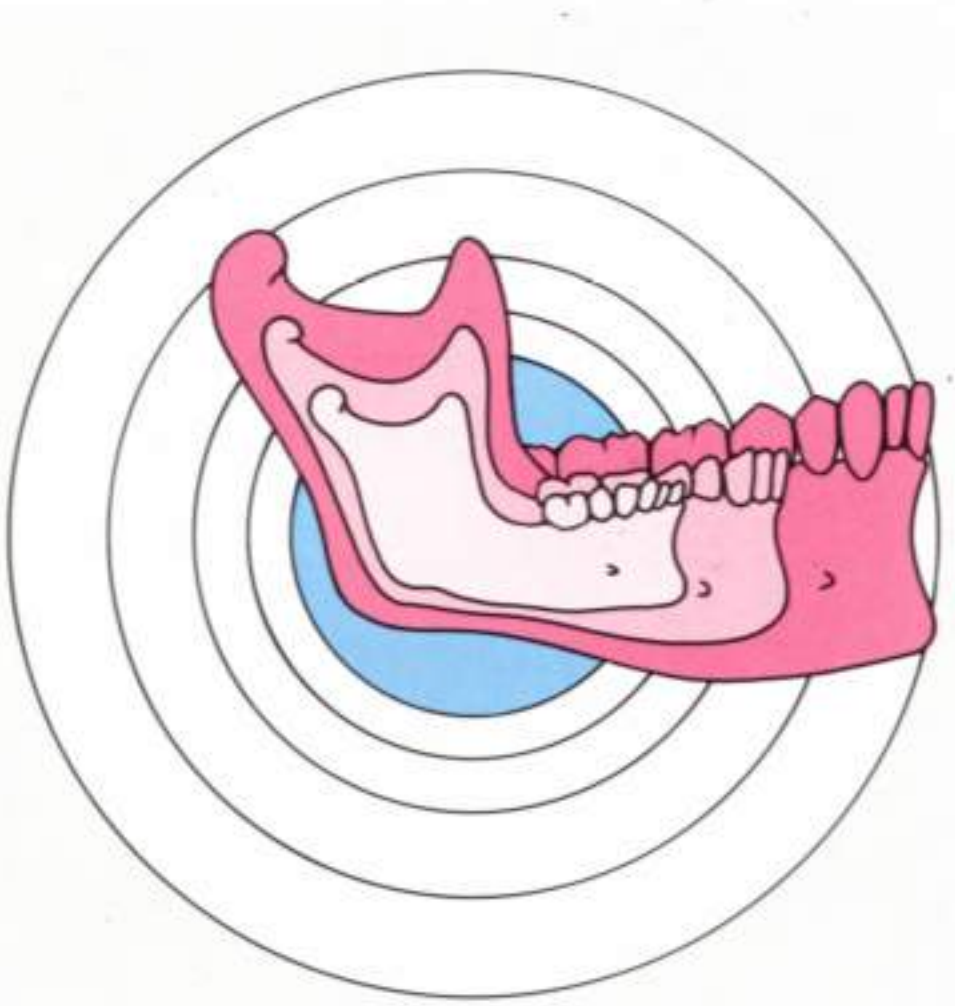
The diagnostic process is not complete until the treatment has been finalized.

Growth of the Craniofacial Skeleton

- **Bone formation**
- **Growth mechanisms**
- **Growth-controlling factors**
- **Possibilities of influencing growth mechanisms**

Various aspects of the growth mechanisms are significant when assessing the etiology of malocclusions and the possible methods of treatment. The development of the craniofacial structures is not merely a symmetrical expansion of the outer bone contours (Fig. 3), but is based on three different growth mechanisms: *Increase in size, bone remodeling, and bone displacement.*

3 Misconceptions about bone growth
Bone growth is not based on symmetrical enlargement of all structures and surfaces, i.e. an adult's mandible does not correspond to the photographic enlargement of a child's mandible, as illustrated. Bone is subjected to a complex remodeling process which simultaneously takes place with increase in size and affects all sections of the structure (according to *Ten Cate*, 1980).



Unlike soft tissue, bone is a mineralized substance and cannot grow by means of interstitial enlargement but only by apposition of the outer, periosteal, and inner, endosteal surfaces.

Deposition and resorption take place simultaneously on the opposing bone surfaces, i.e. the outer and concurrently the inner cortical plates respectively. The deposition on the one side and the resorption of the other side not only causes an increase in proportions but also displaces the bone. New bone formation is closely associated with the *bone remodeling* process during the entire growth period. The two mechanisms must be combined in order to ensure a well-balanced increase in dimensions of the bone structures whiles maintaining their shape and proportions. The third principle which applies to facial growth is *bone displacement,* and is based on the process by which adjacent bones move away from one another, where they are connected by articular joints (sutures, synchondroses, condyles), due to their increasing size.

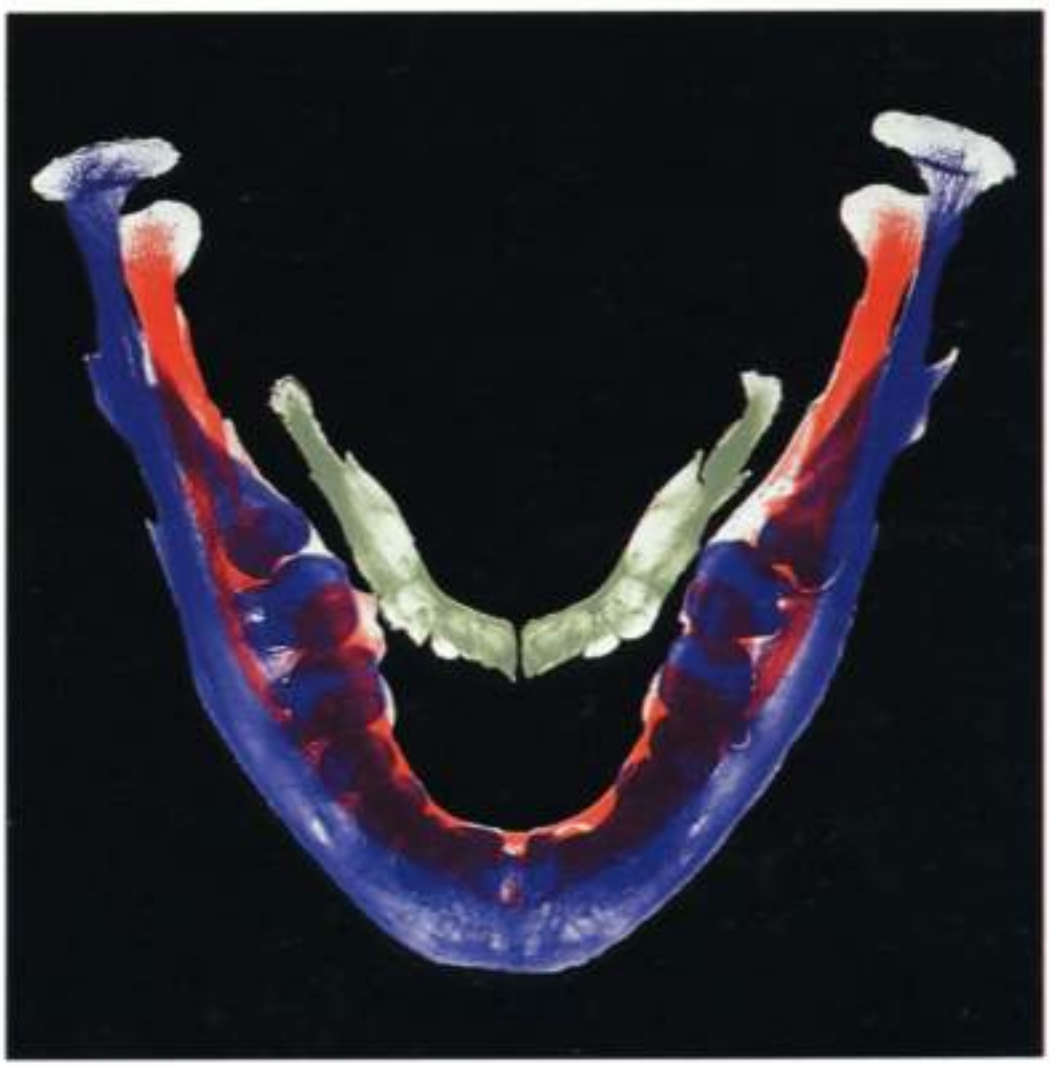
The various growth mechanisms of the facial skeleton are governed and influenced by endogenous and exogenous factors, respectively, during the entire development period.

Mandibular growth

4 Various stages of mandibular growth superimposed on the condylar region
Radiograms of the mandibles of a newborn baby, a 5-year-old and an adult superimposed on one another. The anterior displacement of the mandible, which takes place during development, is quite apparent.

The movement is directed simultaneously forward and downward.

5 Macerated mandibles of a neonate, a 5-year-old and an adult
Growth is considerably faster during the early postnatal period than during adolescence. The radiograms of the bones shown in this illustration are superimposed on one another in Figs. 4 and 6.



6 Various stages of mandibular growth superimposed on the gonial region
Due to the diverging growth direction of the two rami, most of the transverse development of the mandible takes place in a posterior direction. The increase in width anteriorly is minimal. Superimposing the different mandibles shows the regional remodeling processes which take place parallel to the increase in proportions.

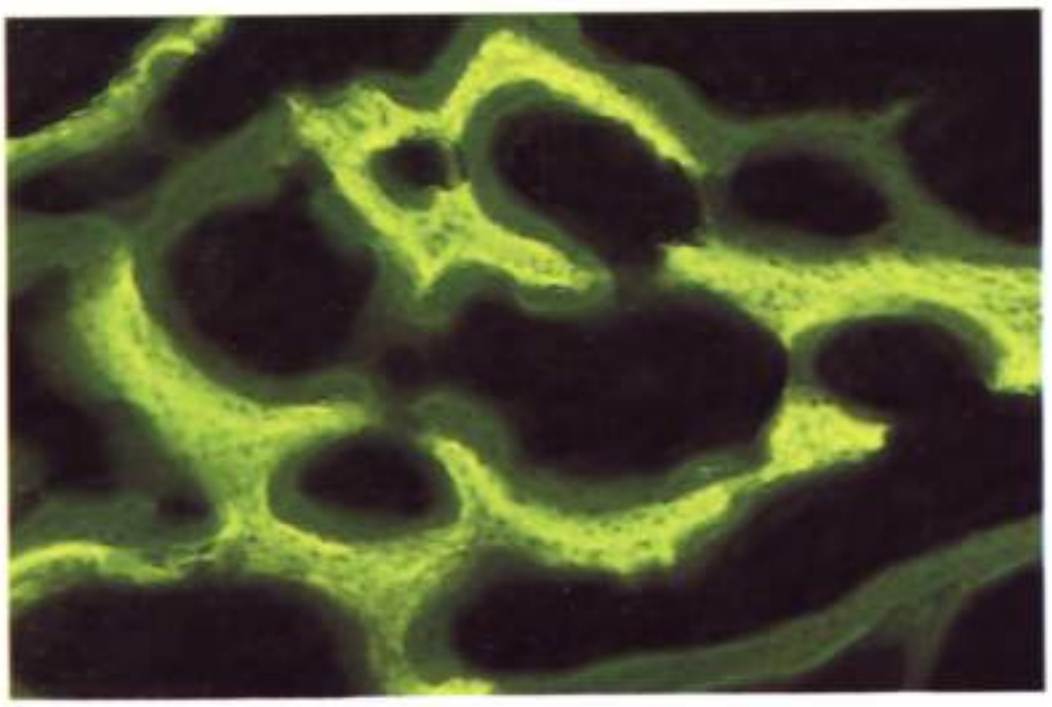
Intramembranous Ossification

Intramembranous ossification applies to two types of bone:

- Bundle bone
- Lamellar bone

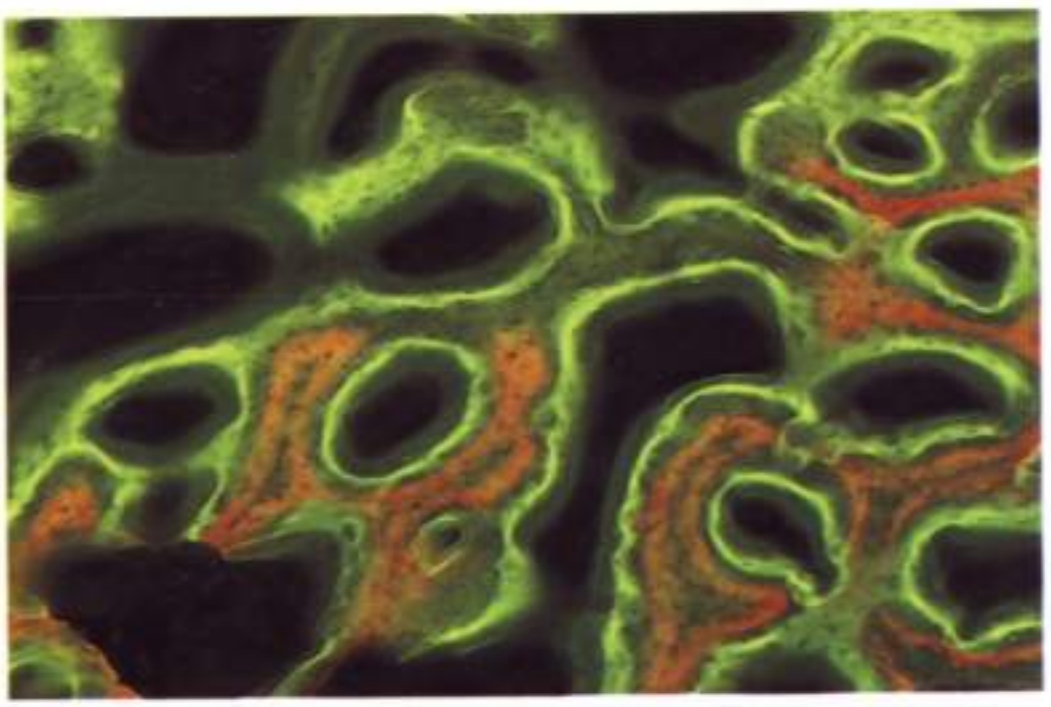
Bundle bone develops directly in uncalcified connective tissue. Osteoblasts, differentiating from the mesenchyme, excrete an intercellular substance containing collagen fibrils. This osteoid matrix calcifies by depositing apatite crystals. These centers of primary ossification exhibit only minimal calcification density. The apatite deposit is mostly irregular and exhibits a net-type structure in both the cortical and medullar areas (Fig. 7). Mineralization takes place very rapidly (several ten thousandths of a millimeter per day) and can occur simultaneously over a large area. Apatite deposition increases with time (Fig. 8). The bone tissue is only then considered "mature" when the crystals are arranged in the same direction as the collagen fibrils. The bone tissue separates into outer cortices and a medullar area, which is then dissolved by resorption; this process takes place parallel to the advancing bone formation. The surrounding connective tissue differentiates into perios-

Intramembranous ossification

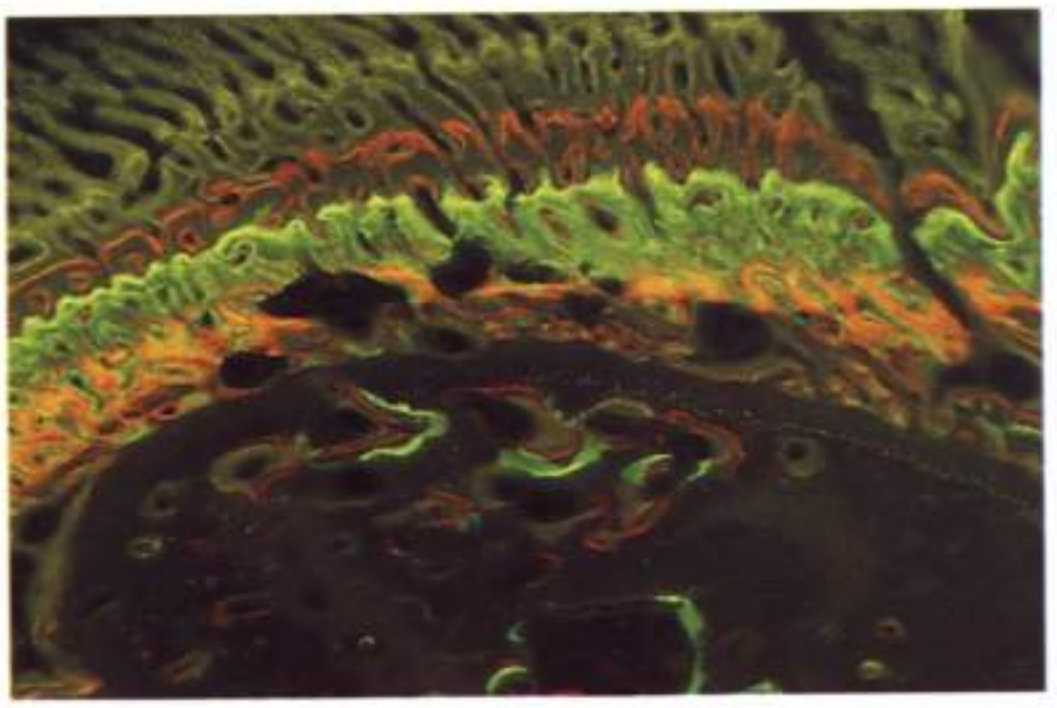


7 1st phase
Deposition of apatite in the connective tissue matrix. This results in a three-dimensional network of loose-packed bundle bone.

The mineralized tissue particles fluorescense yellow under the microscope (tetracycline staining, fluorescence with blue light excitation).



8 2nd phase
Deposits of lamellar bone (yellow) on the spicules of bundle bone (orange). The resulting bone is more compact. Either a cortical bone or trabecular bone is formed depending on the localization (vital staining; fluorescence with blue light excitation).



9 3rd phase
Periosteally derived cortex composed of bundle bone.

The periosteal, radiating spicules of bundle bone can be seen on the exterior. It is quite apparent that the bone deposited first is thicker (vital staining; fluorescence with blue light excitation).

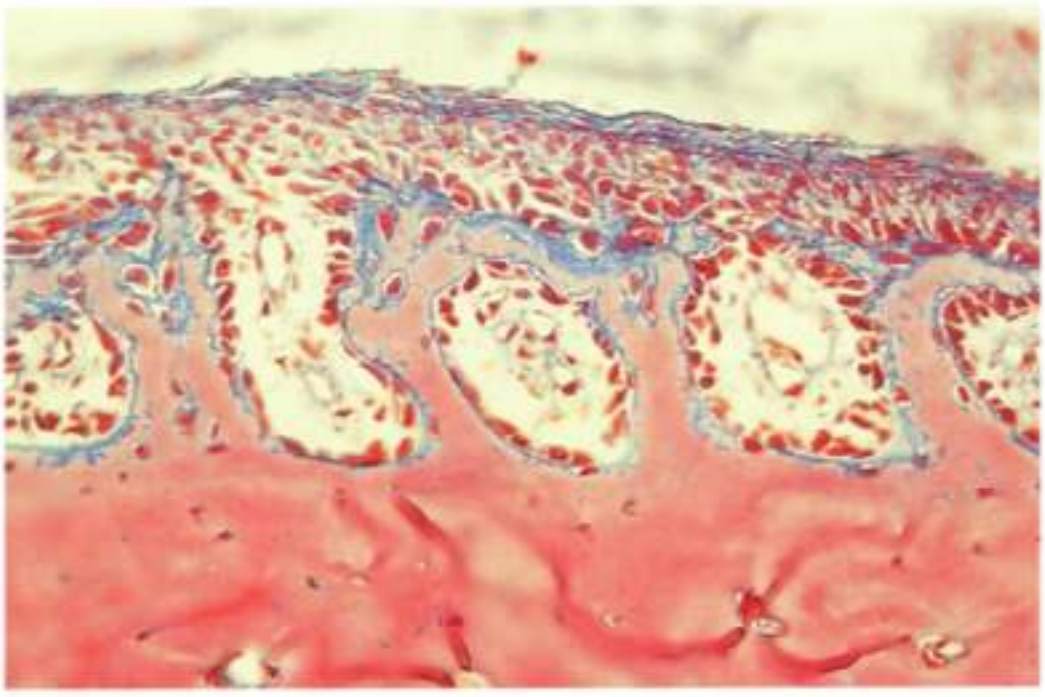
teum. Its inner layer is rich in cells, has an osteogenic function and contributes to the formation of the thicker sections of bone (Fig. 9) as well as the endosteum.

Bundle bone which, in adults, is usually only formed during rapid bone remodeling, is often only a preliminary type of ossification. It is reinforced by lamellar bone.

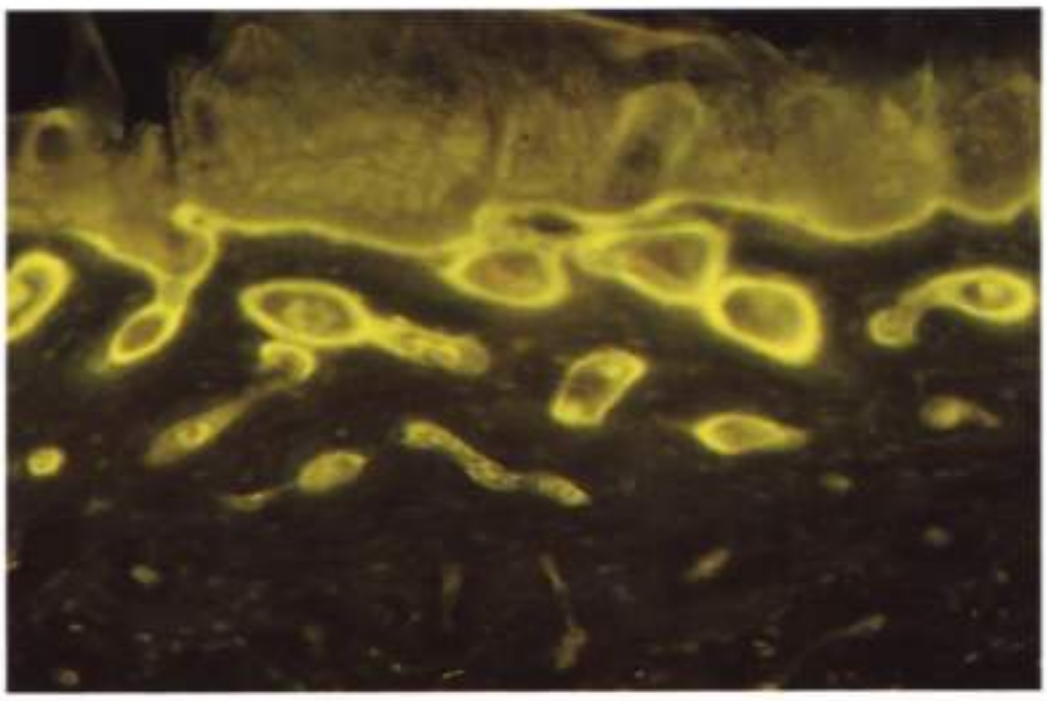
Unlike bundle bone formation, *lamellar bone development* only takes place in a mineralized matrix (e.g. calcified cartilage or bundle bone spiculae). The mesh in the bundle bone is filled to reinforce it, until compact bone is formed. Osteoblast formations appear on the mineralized matrix, which then form circles and surround the intercellular substance around a central vessel in several layers (Haversian system or osteon) (Figs. 10, 11). Lamellar bone is formed at a rate of 0.7–1.5 microns per day (Fig. 12). The tissue exhibits a complicated arrangement of fibers, which is responsible for its mechanical properties (Pauwels, 1965). The arrangement of the apatite in the concentric layers of fibrils meets the functional requirements.

Lamellar bones are subject to continual deposition and resorption which can be influenced by environmental factors, for example, orthodontic treatment.

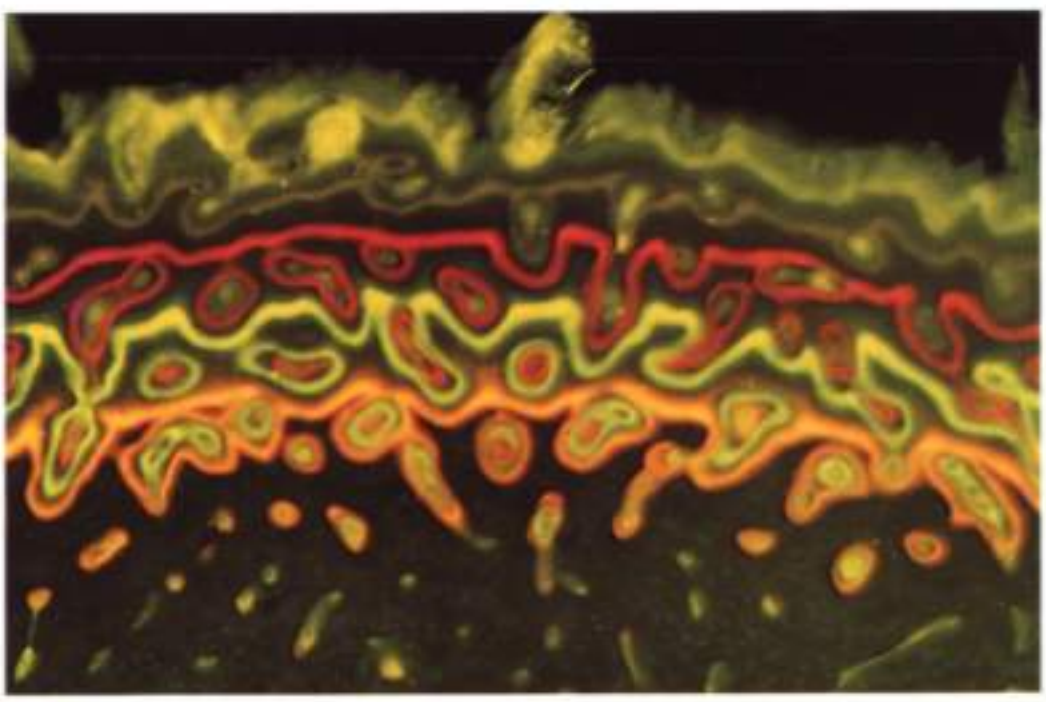
Lamellar bone formation



10 Formation of primary osteons
The trabeculae of bundle bone that are deposited periosteally flow together to form canals, which are lined with osteoblasts. These are then narrowed down to the lumen of the blood vessels by concentric deposition of lamellar bone.



11 Migration of primary osteons
The primary osteons drift deeper due to further surface deposition of bone (calcein staining; fluorescence with blue light excitation).



12 Conversion to Haversian systems
While bone growth is continuing, the primary osteons, which have drifted deeper, are being filled even more.

Further layers of lamellar bone are deposited on the surface at the same time (vital staining; fluorescence with blue light excitation).

Enchondral Ossification

During enchondral ossification, tissue which is to become bone is first formed in cartilage and, apart from around the joints and epiphyses, is surrounded by perichondrium which later forms the periosteum. Osteogenesis is based on cartilage ossifying to bone. Regardless of which material existed previously (connective tissue or cartilage), the actual bone formation process always takes place according to the same principle (refer to section "Intramembranous Ossification").

Depending on the locality of the mineralization, it can be differentiated between:

- Perichondral ossification
- Endochondral ossification

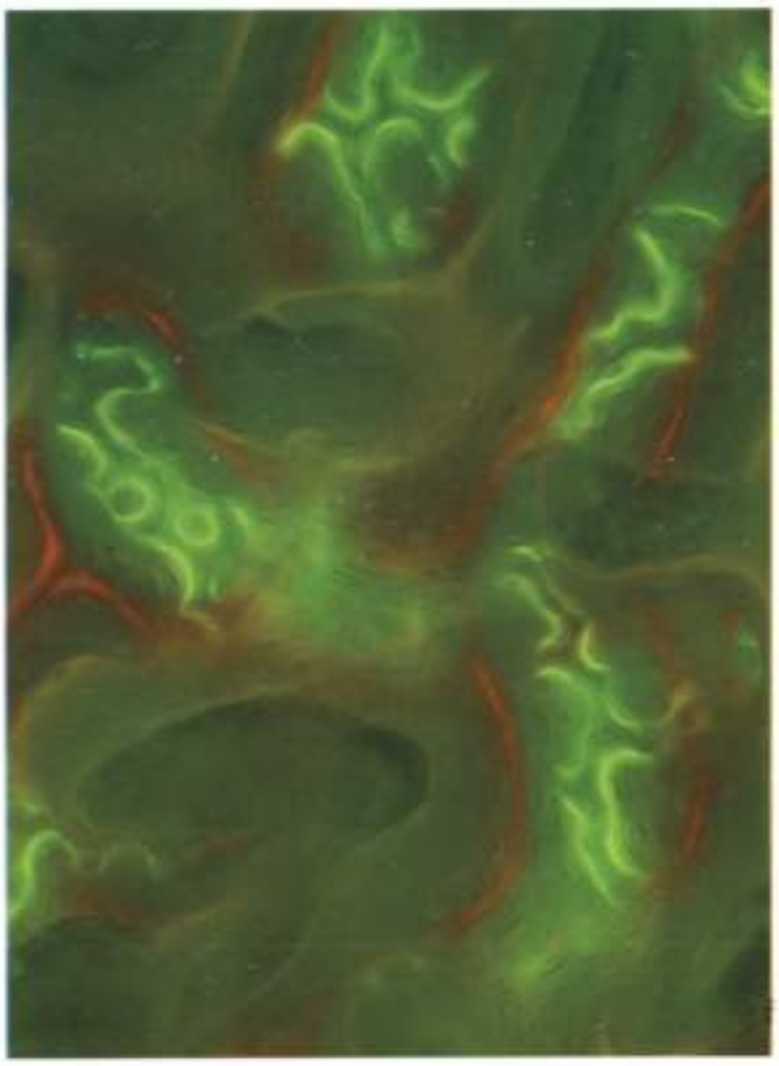
Both types play a role in the ossification of long bones whereas only endochondral ossification takes place in the short and flat bones.

Perichondral ossification commences at the perichondrium. The mesenchymal cells of the tissue become differentiated to osteoblasts, which surround the diaphyses with a bone sleeve prior to endochondral ossification, thus indirectly influencing its direction.

Endochondral ossification commences with characteristic changes in the cartilage cells (hypertrophied cartilage) and their surrounding intercellular matrix (calcium deposits), i.e. the formation of the so-called primary spongiosa. Blood vessels and mesenchymal tissue then penetrate these areas from the perichondrium. The transported connective tissue cells become differentiated to osteoblasts and resorption cells, e.g. chondroclasts which erode the cartilage in a cavern-like pattern.

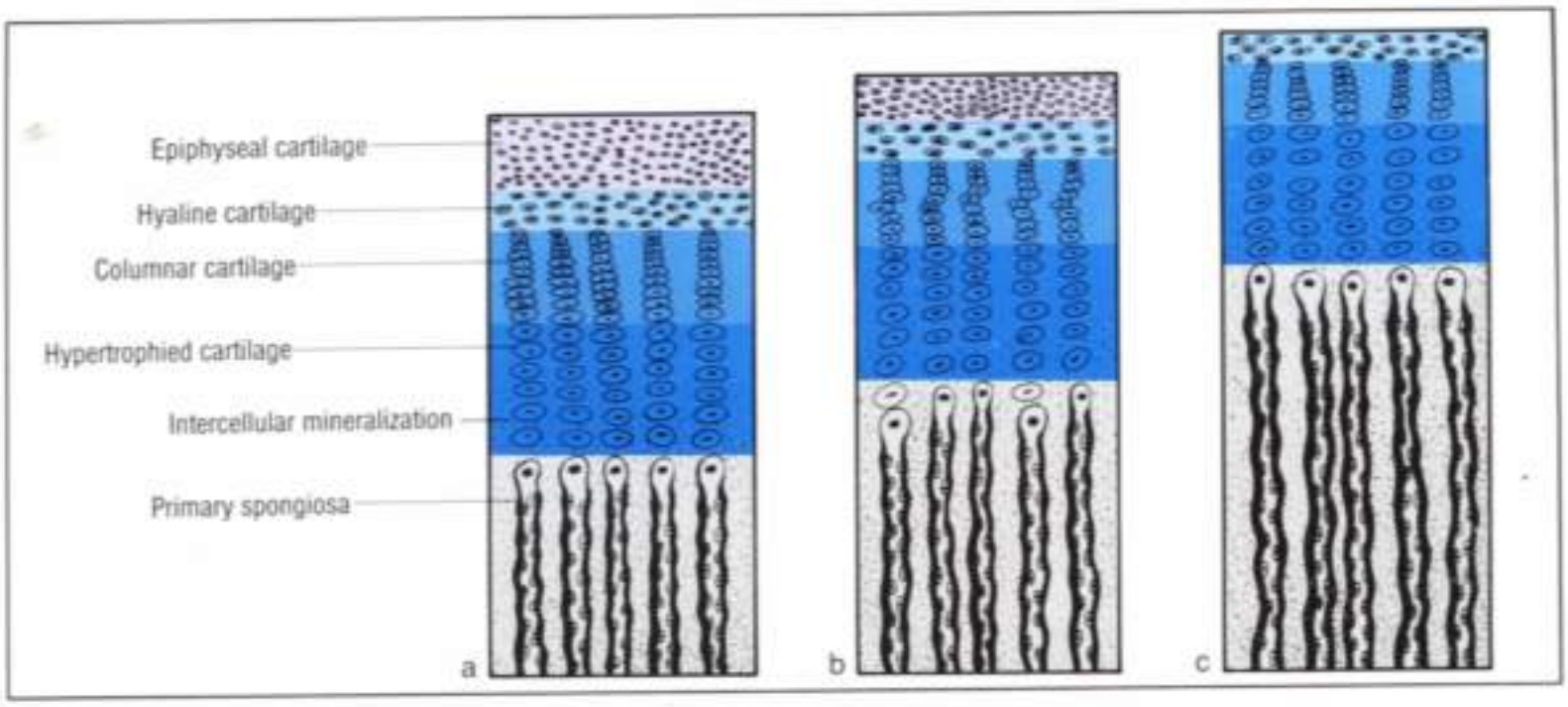
13 Endochondral ossification
Remnants of mineralized cartilage (serrated green structures) form the centers of deposition for lamellar bone layers (red and yellow).

Right: The result is either spicules of primary spongiosa (as illustrated) or, when centered in the cortical layer, compact bone. Right: Section through uncalcified bone (differential interference contrast, (DIC), according to *Nomarski*).



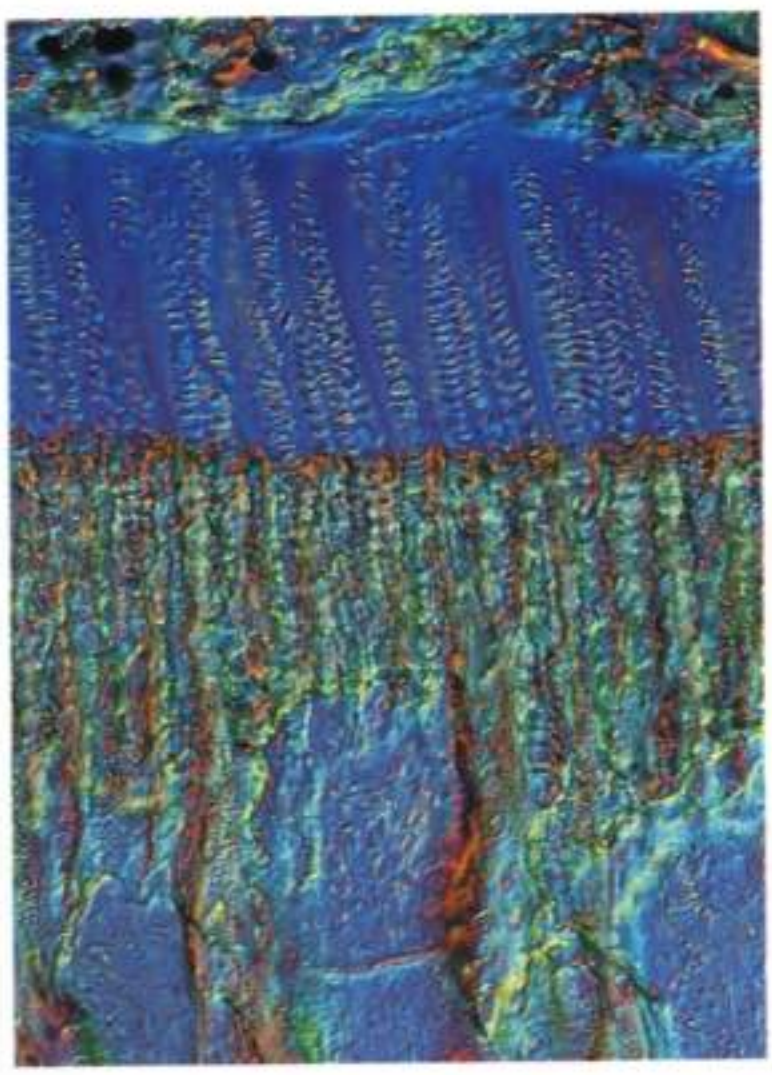
The osteoid layer is deposited on the remaining calcified spicules of the cartilage and then mineralized to form bony spongiosa, with a fine, reticular netlike structure which has cartilage fragments between the osseous spicules (Fig. 13). The bony spongiosa can be converted to compact bone by filling its cavities (Fig. 13). Both endochondral and perichondral bone *growth* take place toward the epiphyses and joints. The increase in length of the bones during endochondral ossification depends on the growth of the epiphyseal cartilage. Once the epiphyseal line has been closed, the bones no longer increase in length. Unlike bones, cartilage growth is based on both appositional and interstitial growth. In those areas where cartilage is being converted to bone, various characteristic zones, in accordance with the individual stages, can be differentiated which continually blend with one another during the conversion process (Fig. 14). The ossification of "primary" cartilage (e.g. epiphyseal cartilage) differs from that of "secondary" cartilage (e.g. condyle cartilage).

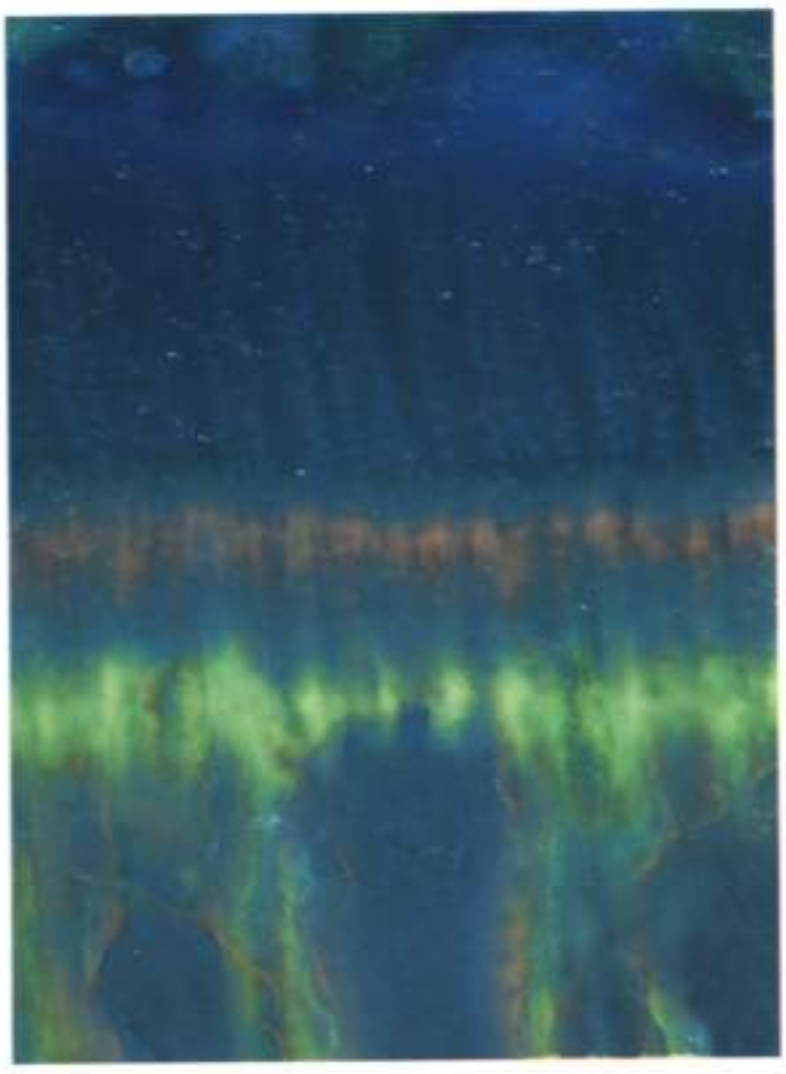
Environmental influences (for instance, functional orthopedic mechanisms) have a stronger effect on the *condylar cartilage* due to its more superficial localization.



14 Growth of the epiphysial cartilage of long bones

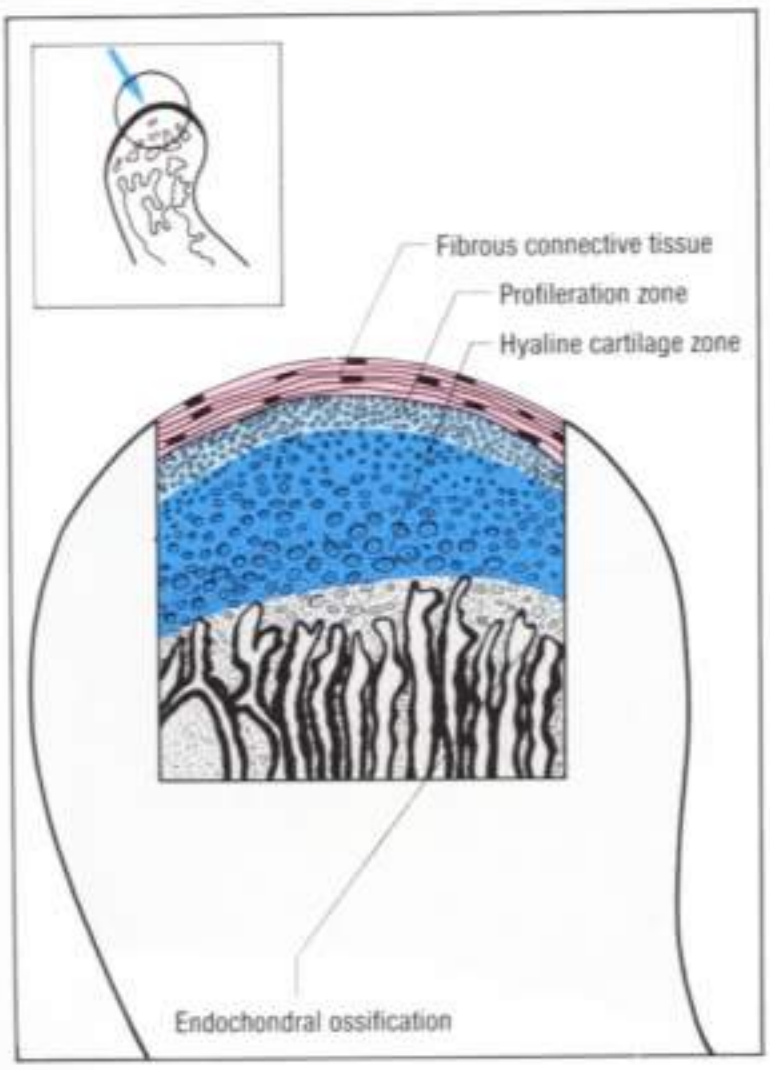
a Schematic view of the epiphyseal plate. The growth is based on the cell division rate of the columnar cartilage zone.
b During the growth period of the cartilage, the columnar cartilage zone becomes converted to hypertrophied cartilage zone which, in turn, becomes the primary spongiosa zone.
c With further ossification the cartilage zone advances to the upper edge of the diagram (*Enlow*, 1968).

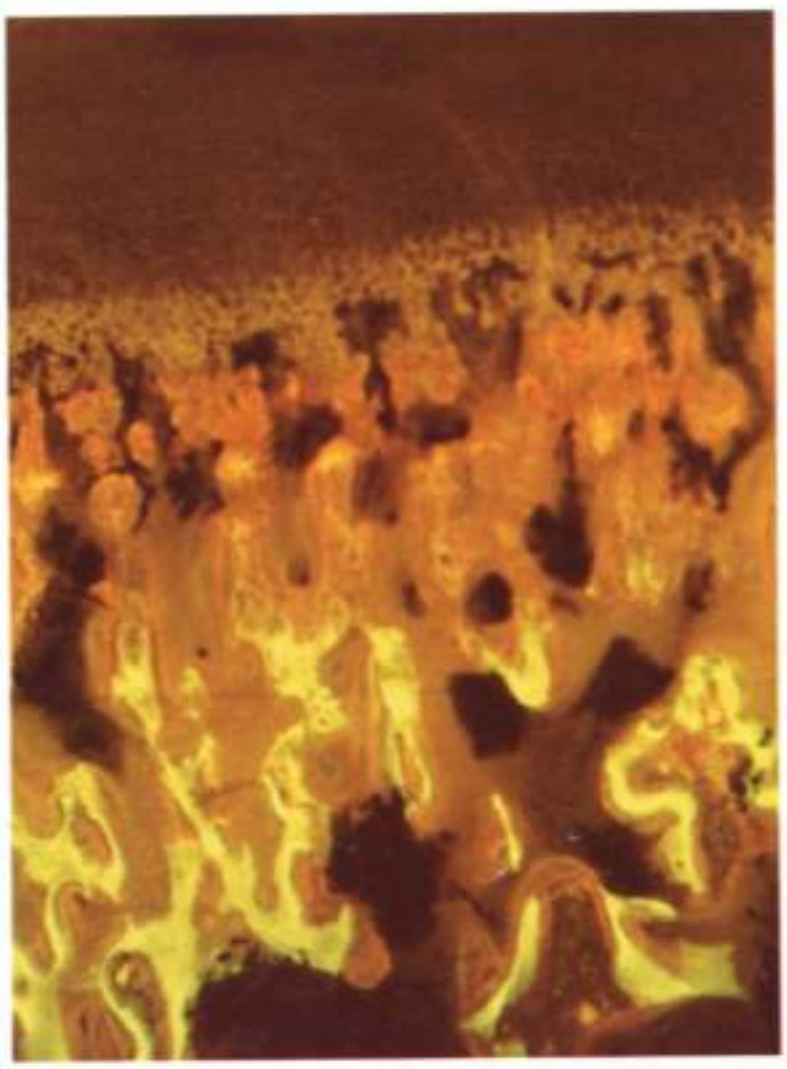




15 Epiphyseal cartilage
Characteristic structure of growing bone: Epiphyseal spongiosa, thin hyaline cartilage zone, columnar cartilage, hypertrophied cartilage. The ground substance begins to calcify and hypertrophied cartilage cells to dissolve in the underlying mineralization zone (DIC according to Nomarski). The calcified cartilage is partly resorbed and forms the basis for the spongiosa spicules.

Right: Fluorography (UV excitation) shows how the mineralized layers (marked with tetracycline [yellow] and alizarine [pink] at 1-week intervals) retreat from the epiphyseal cartilage zone.





16 Condylar cartilage of the temporomandibular joint
The condylar cartilage is a secondary type of cartilage, which was transformed phylogenetically from the periosteum. Histologically, condylar cartilage is considered to have four different zones (longitudinal section):

1) Dense, fibrous connective tissue zone sparsely vascular;

2) Proliferation zone of undifferentiated connective tissue cells (mitotic zone), which become differentiated to chondroblasts;

3) Hyaline cartilage zone with randomly distributed chondroblasts and hypertrophied cells. The matrix of these cells is more calcified toward the condyle;

4) Endochondral ossification zone, in which the cartilage is resorbed and replaced with trabecular bone.

Right: The cartilage and mineralization zones (vital staining; fluorescence microscope).

Growth Mechanisms

- Endosteal and periosteal bone growth
- Cortical drift
- Relocation and remodeling
- "V" principle
- Surface principle
- Growth fields
- Displacement
- Growth equivalents

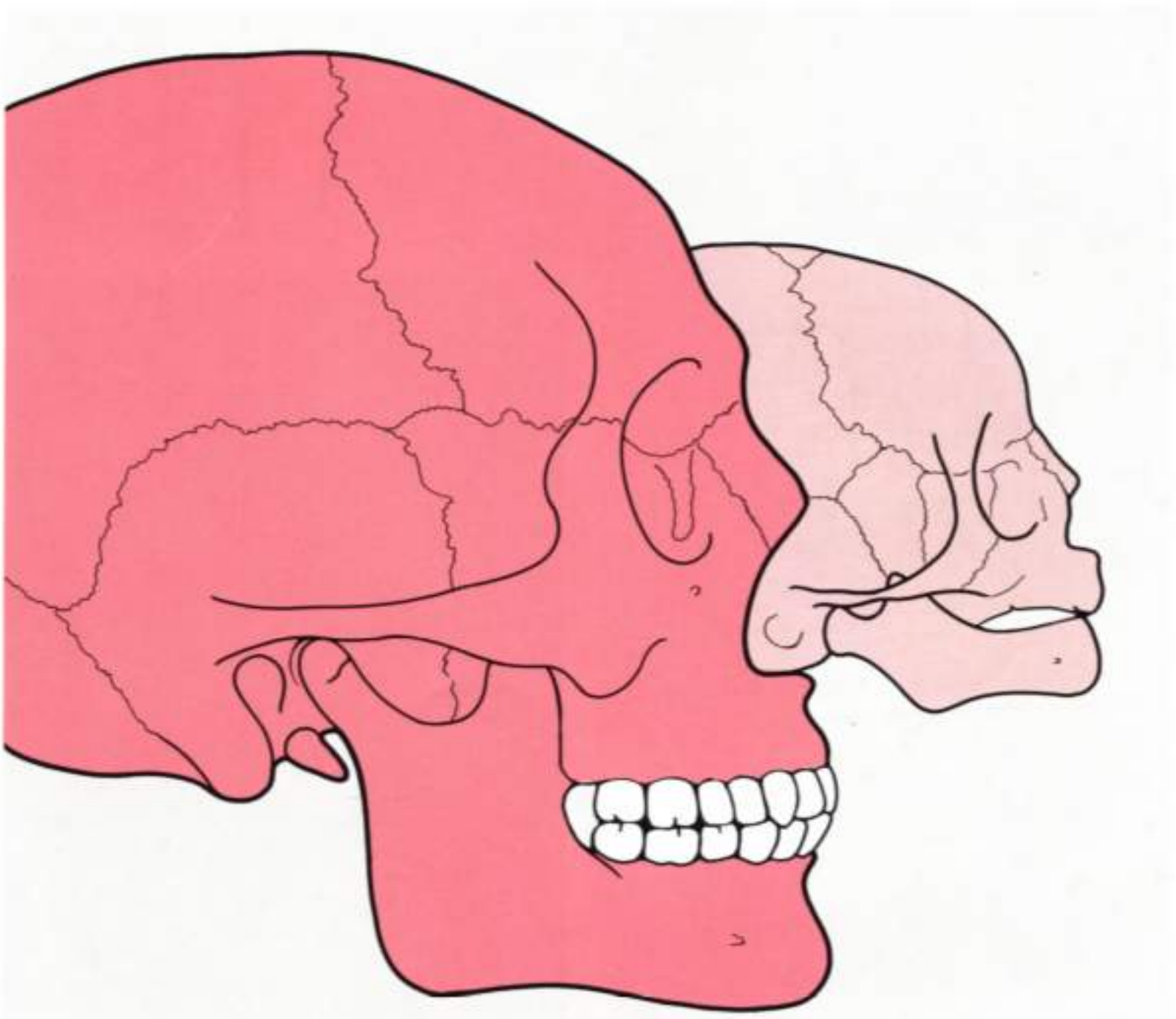
Bone growth takes place according to several basic principles, which can also be used to explain the growth processes of the facial skeleton.

The theory that bones grow by simple symmetrical enlargement is wrong. Such a simple growth mechanism could not possibly create such a complex and differentiated morphology as that of the mandible or maxilla. Such morphology demands differential growth mechanisms and different types of development for the individual bones.

The following two mechanisms are important for bone growth in the facial and cranial regions:

– Direct bone growth by means of deposition and resorption processes on the bone surfaces, which cause the cortical plate to drift;

– Displacement of the entire bone due to growth of the bone itself or expansion of adjacent structures.



20 Bone relocation and remodeling
The hard palate of a newborn baby is directly beneath the infraorbital rims. Progressive enlargement of the nasal cavities displaces the palate downward during growth of the facial skeleton.

Simultaneously with the downward movement, the bones are remodeled by resorption and apposition and increase in size. In adults, the space which formed the hard palate and maxillary arch of the infant is occupied by the expanded nasal chambers (*Ten Cate*, 1980).

Endosteal and Periosteal Growth

Approximately half of the cortical plate of the facial and cranial bones is formed by the outer surface, i.e. the periosteum, and the other half by the inner surface, i.e. the endosteum.

Appositional layers of cortical bone can originate entirely from the periosteum or the endosteum (Fig. 21).

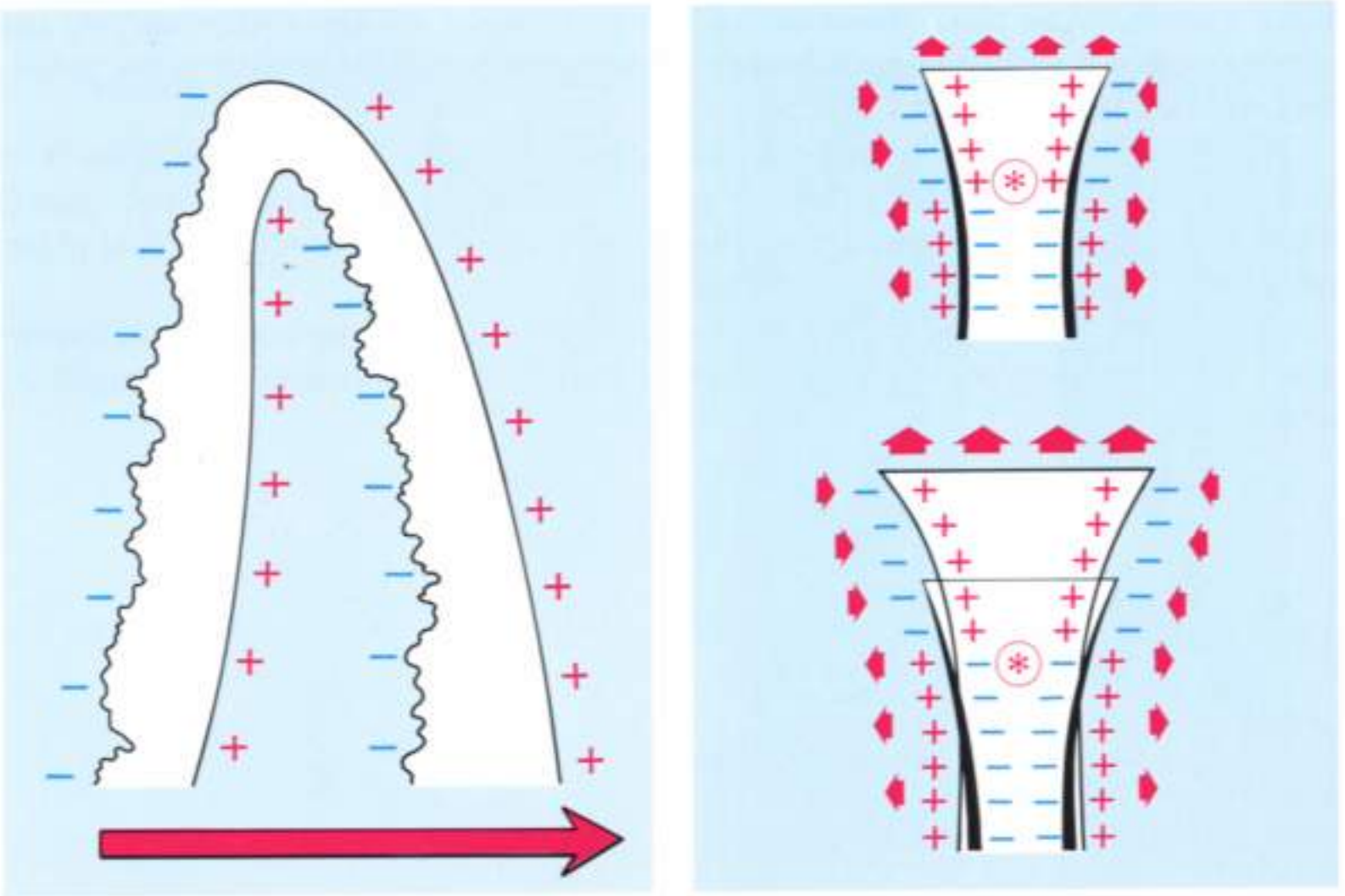
In other cases, the same cortex is composed of periosteal and endosteal bone layers which are separated by a so-called *reversal line* (Fig. 22). This type of bone growth indicates that there has been a change in the direction of growth at some time. As new cortical bone is always deposited on the surface facing toward the direction of growth, bone formation originating in the endosteum can, at a later date and after reversal of the direction of growth, evert to a type of periosteal bone formation. The reversal line represents the interface between endosteally and periosteally produced bone layers.

21 Periosteal and endosteal bone formation

\+ = Bone apposition
− = Bone resorption

Left: If the direction of growth remains constant, the right cortical plate is formed periosteally and the left plate endosteally. Both shift in unison in the direction of growth, i.e. to the right.

Right: The direction of growth can change during development of the bone. In the area marked with an asterisk, bone formation initially occurs endosteally (above) and, at a later date after reversal of the direction of growth, periosteally (below) (*Enlow*, 1982).



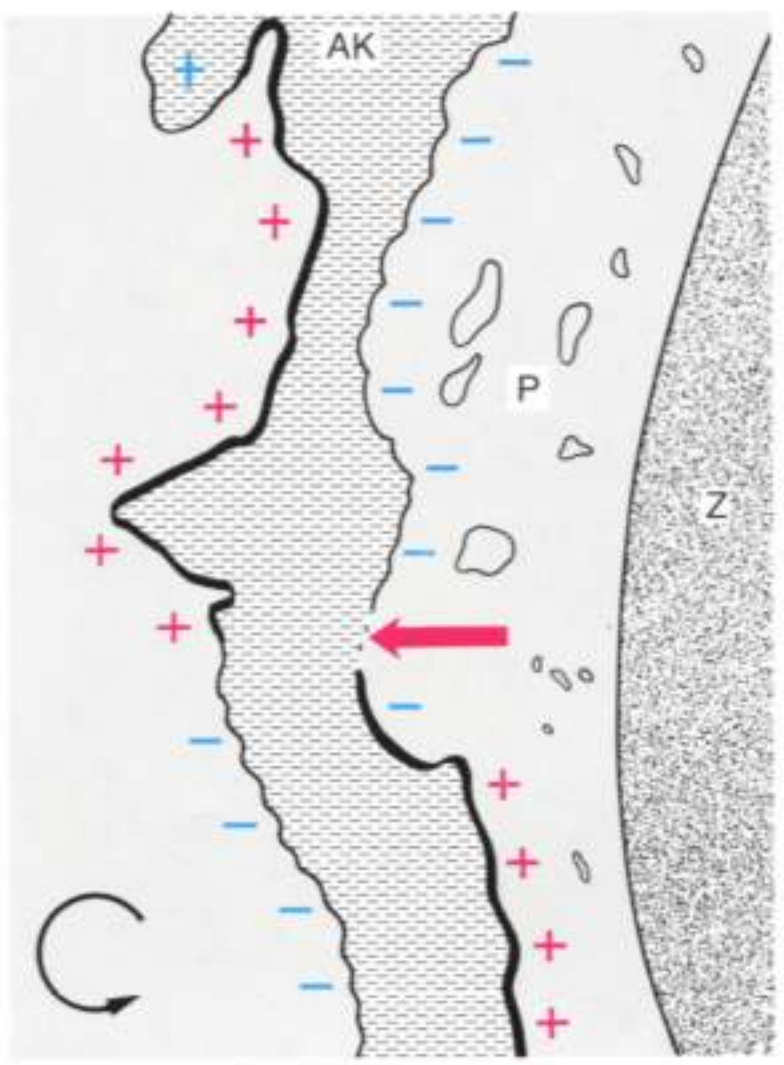
22 Reversal line

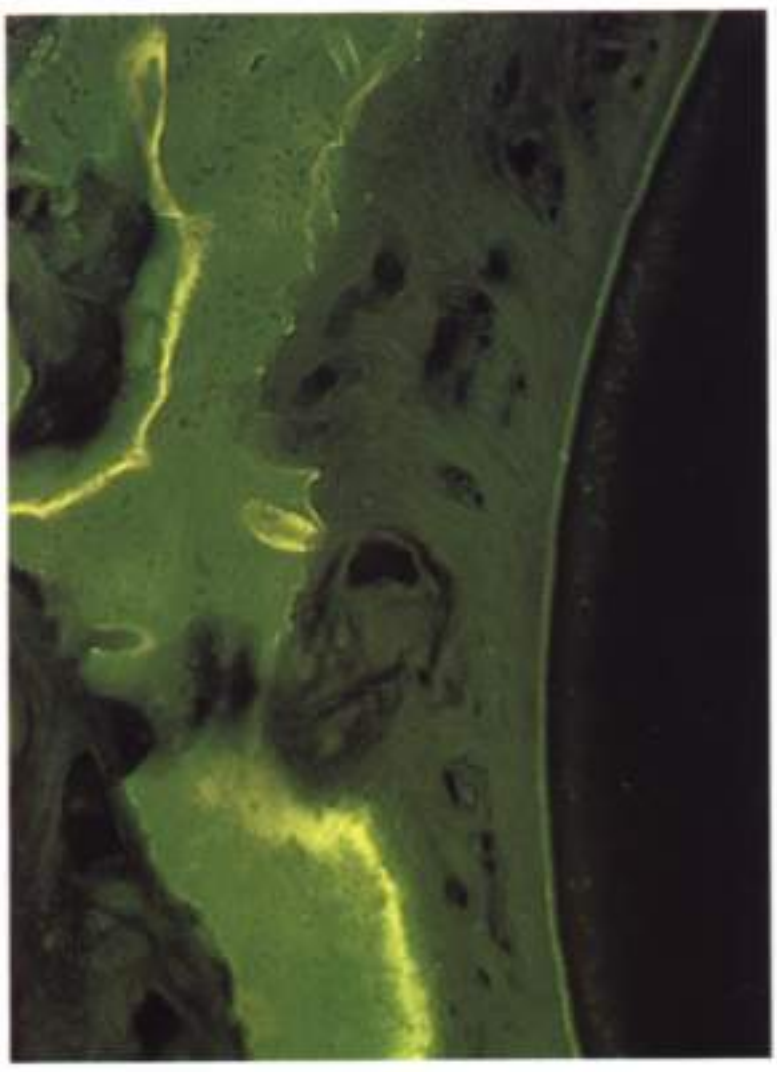
AK = Alveolar bone
P = Periodontal space
Z = Tooth root

The interface between periosteally and endosteally formed bone is termed the reversal line (→ = reversal line).

Right: Section through an alveolar bone. The yellow staining indicates that endosteal bone formation takes place in the upper section of the surface facing the tooth and periosteal formation in the lower section. This leads to rotation of the bone structure (fluorescent microscopic view after tetracycline staining).

Left: Line-drawing of the histologic section.



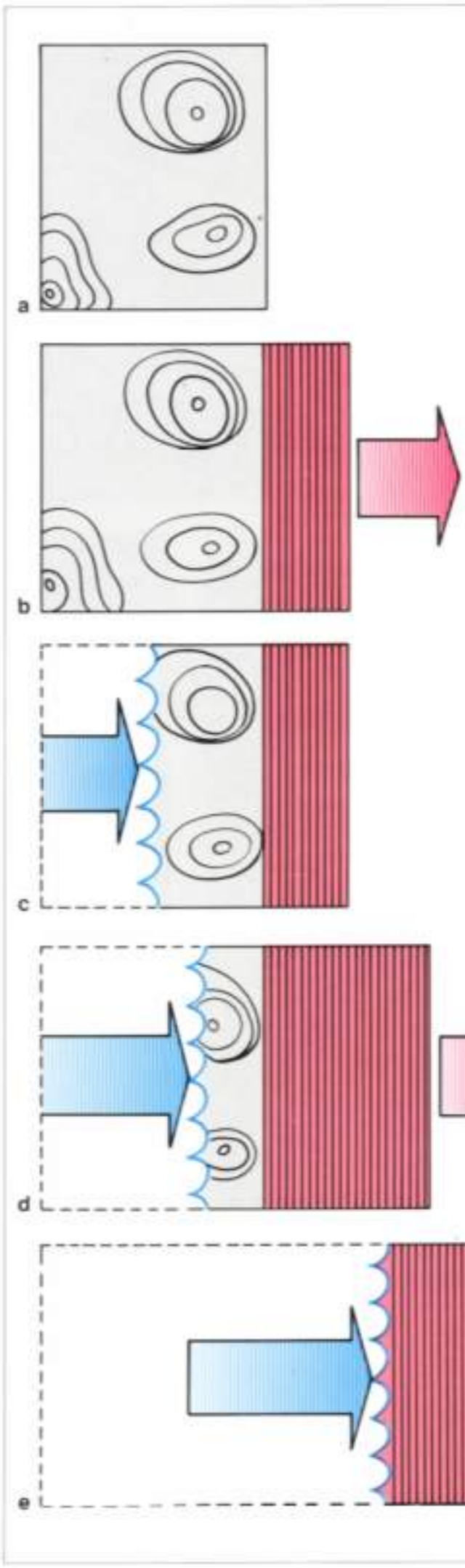


Cortical Drift

All bone structures have one growth principle in common, which was termed "drift" by Enlow (1963).

The cortical plate can be relocated by simultaneous apposition and resorption processes on the opposing periosteal and endosteal surfaces (cortical drift). The bony cortical plate drifts by depositing and resorbing bone substance on the outer and inner surfaces, respectively, in the direction of growth (Fig. 23). If resorption and deposition take place at the same rate, the thickness of the bone remains constant. Should more bone be deposited than resorbed, the thickness of the structure increases. During the developmental period, deposition takes place at a slightly faster rate than resorption, so that the individual bones slowly enlarge.

The *teeth* follow the drift of their alveolae while the jaw is growing and thus maintain their position within the surrounding bony structures despite the bone displacement (Fig. 25).



23 Cortical drift
(Diagrammatic view)

a Cortical plate of a bone.

b Increase in thickness due to apposition on one of the surfaces.

c When the resorption process on one side of the bone exceeds the apposition process on the opposing side, the thickness of the bone will be reduced.

d When resorption on one side of the bone corresponds in magnitude to apposition on the opposing side, the bone will drift without changing its size.

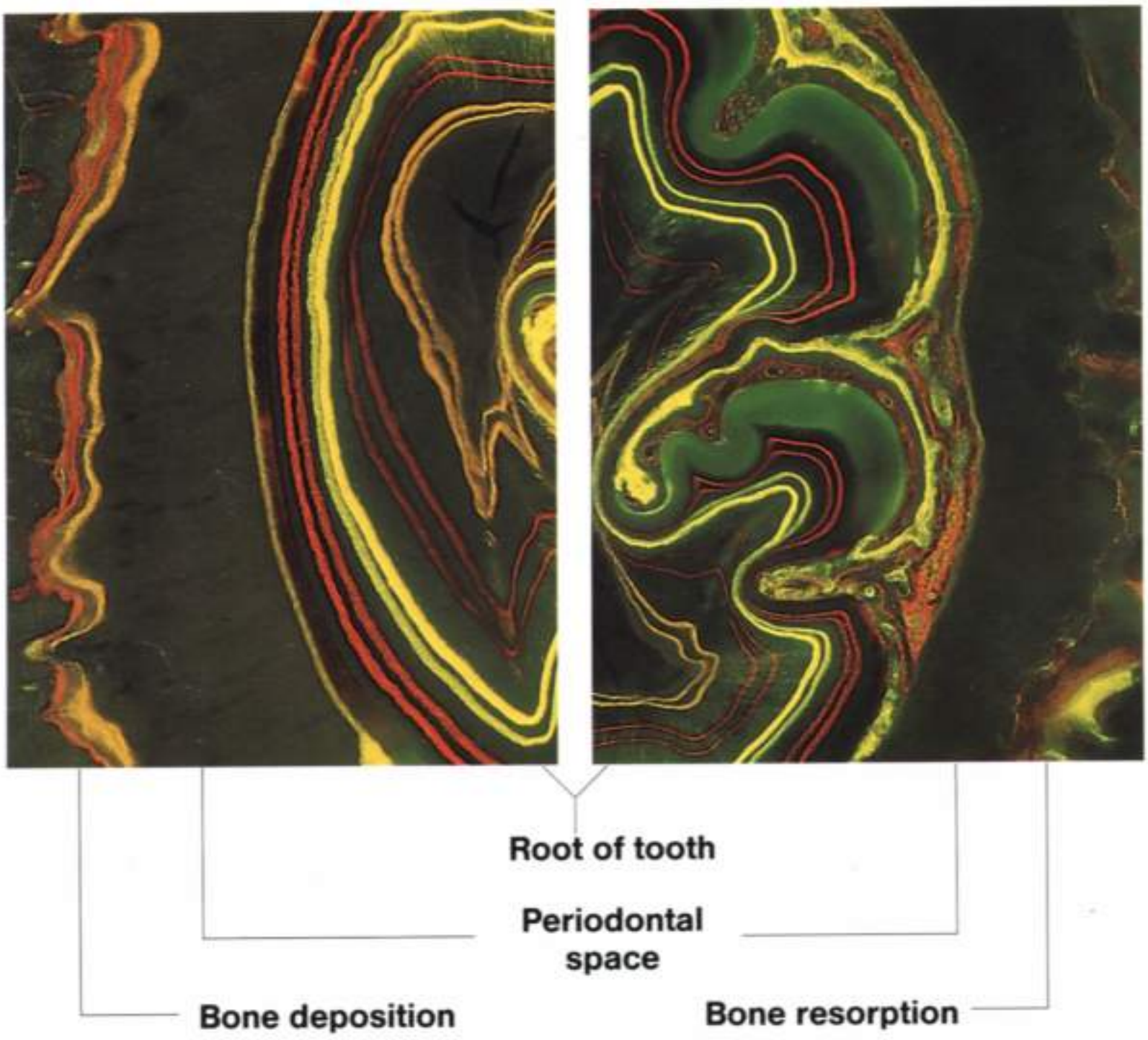
e The cortical plate has drifted completely to the right when compared to its original position in a) by the process of surface remodeling (*Ten Cate*, 1980).

24 Cortical drift
Formation of lamellar bone on the endosteal surface and resorption on the periosteal surface cause the entire cortex to drift. Should both surfaces drift at the same rate, the dimensions of the bone will be maintained.

The asymmetric coloration around the osteon shown in the center of the picture indicates the direction of drift (marked at 1-week intervals using seven different vital dyes; fluorescence with UV excitation).

25 Drift of alveolar sockets during growth
Resorption of the alveolar bone on the surface facing toward the direction of drift and apposition on the opposite alveolar side. By this means, the tooth retains its anatomic position relative to the alveolar process as the whole bone drifts during growth (Fig. 24). Therefore it is necessary that the localization of the alveolar resorption and apposition processes are identical yet take place in the reverse direction to the periosteal and endosteal processes.

The heavy staining in the dentin (layer-by-layer marking with vital dyes) are caused by the continual growth of the incisors in this rodent.

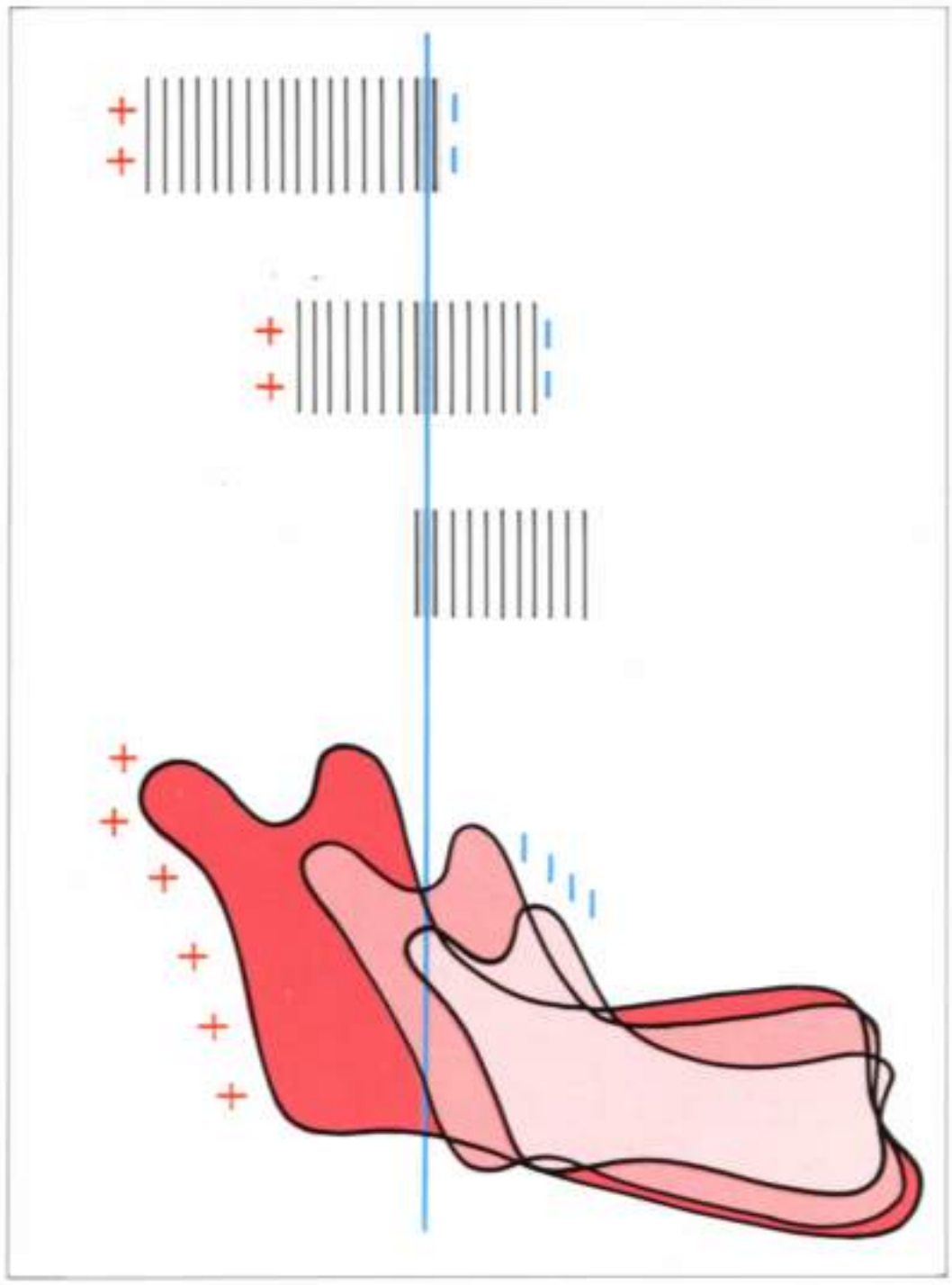


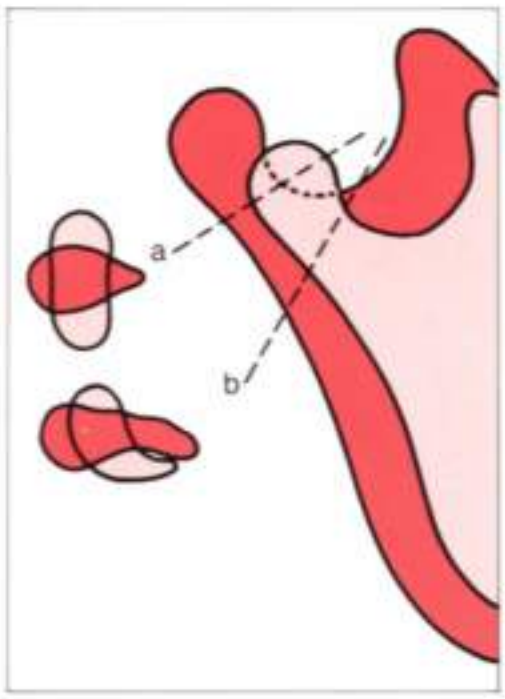
Relocation and Remodeling

Due to new bone deposition on an existing surface, all other parts of the structure undergo shifts in relative position; a movement which is termed *relocation.*

As a result of this process, further adaptive bone remodeling is necessary in order to adjust the shape and size of the area to the new relationship. Selective resorption and apposition processes functionally remodel the area to conform to the new physiological loading.

Relocation and cyclic, structural remodeling are growth mechanisms which are closely related to one another: *Remodeling is based on relocation and is a secondary result of the displacement process.* When one level passes into the next due to growth, its position is taken by the following level which undergoes the relevant structural changes. The information which initiates the remodeling process is contained within the various soft tissues surrounding the bone.

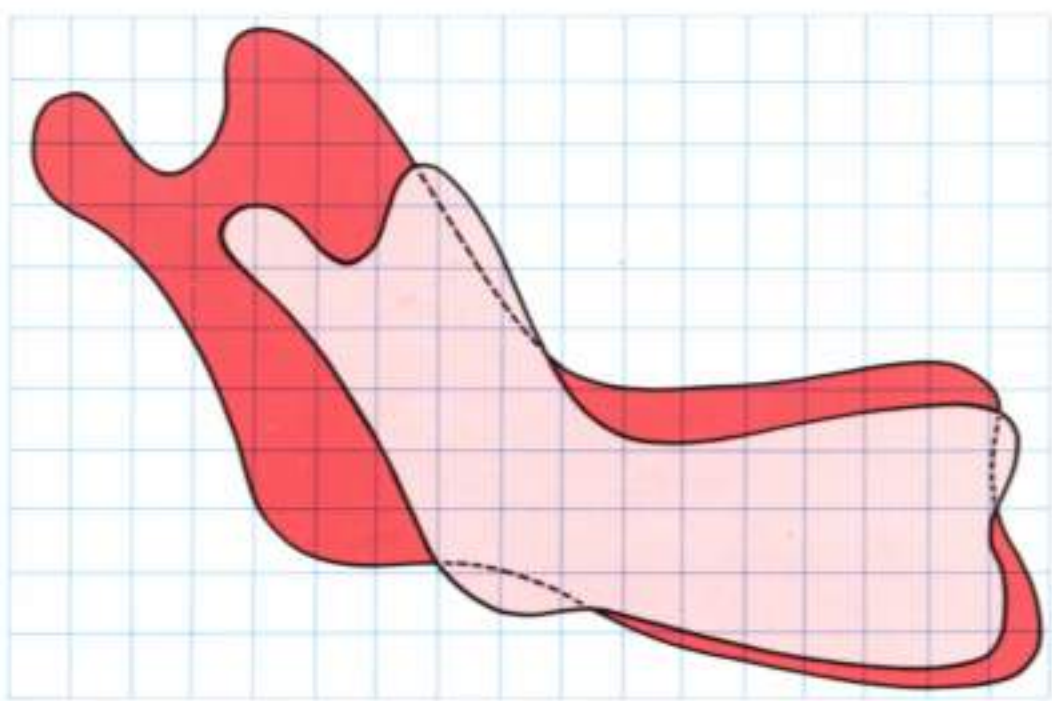




26 Relocation and remodeling
(Diagrammatic view)

The position of the gray zone changes in relation to the original position (A) due to bone apposition (+) and resorption (–). As a result of the level-by-level growth process, the marked area is translocated from the posterior to the anterior border of the ramus, without changing its own position.

Left: Superposition to show the growth processes of the ramus. Parts of the condylar head are converted into the neck of the condyle during the process of relocation. The sections through **a**) and **b**) show the local remodeling changes which are necessary to adapt the form and size of the structures to their new relative positions (*Enlow,* 1982).



27 Relocation and remodeling of the mandible during growth
The remodeling process of the ramus takes place toward the posterior. The body of the mandible becomes lengthened by remodeling parts of the ramus, which simultaneously shifts in backward direction (*Enlow,* 1968).

28 Primary displacement and bone growth

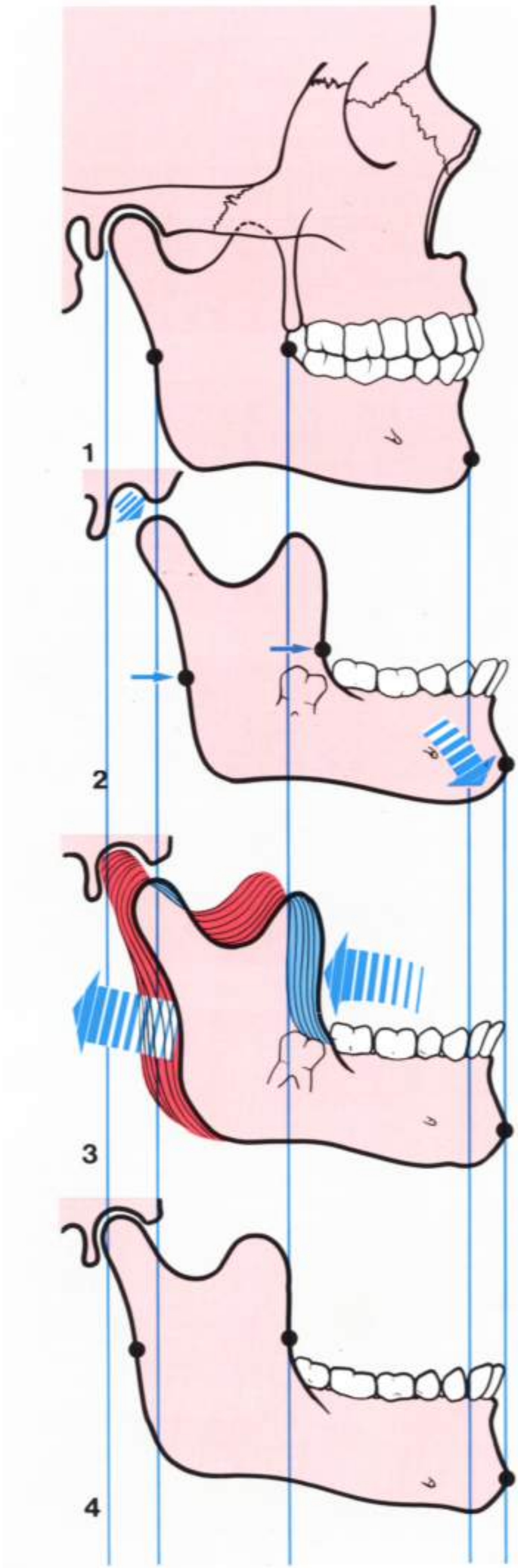
These two basic growth mechanisms are closely interrelated.

Beginning at position (1) the entire mandible is displaced downward and forward (2), away from its articular joints, by the growth of the surrounding soft tissues.

This translatory movement stimulates the enlargement and remodeling (3) of the condyles and rami which take place parallel to displacement.

The bone growth processes are directed upward and backward by an amount that equals the displacement of the mandible.

The changes resulting from these combined processes are shown in (4) (*Ten Cate*, 1980).



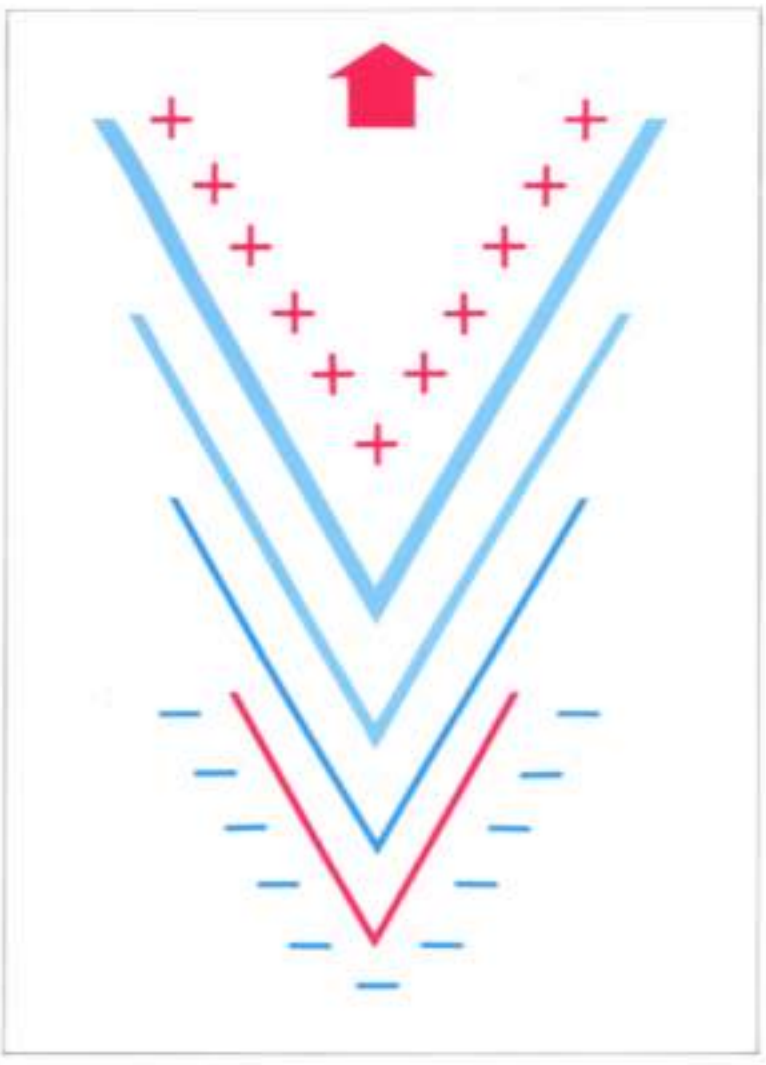
The "V" Principle

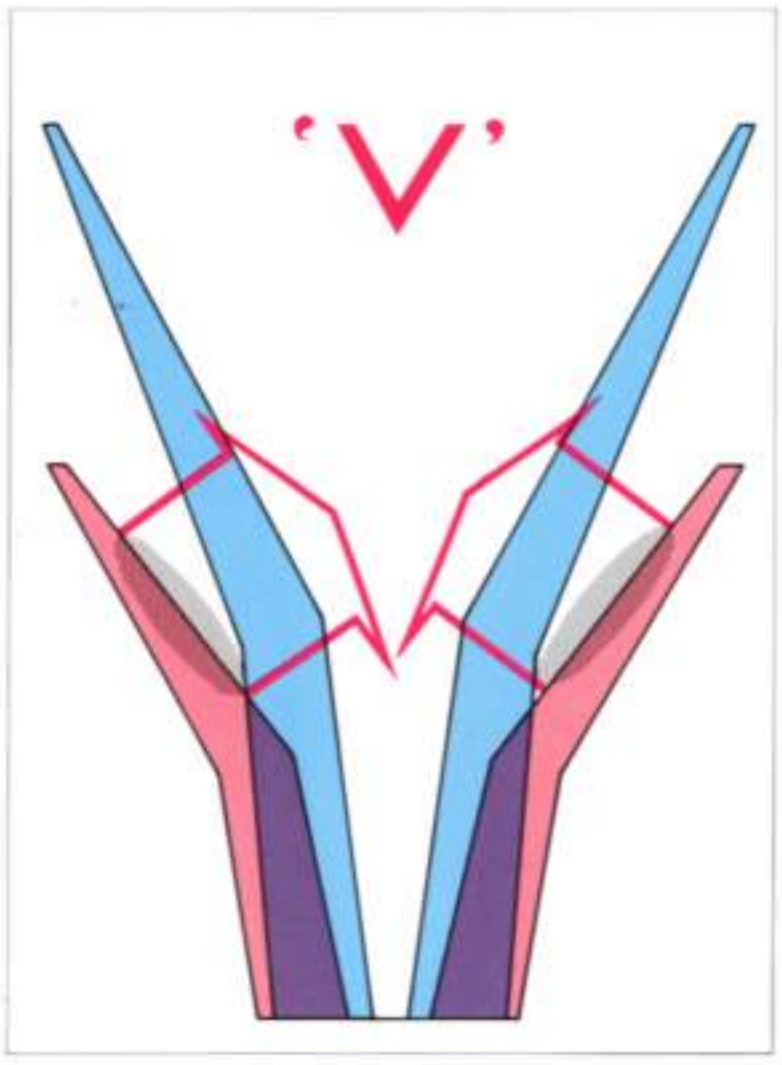
The "V" principle is an important facial skeleton growth mechanism, since many facial and cranial bones have a "V" configuration or "V"-shaped regions.

Such areas grow by bone resorption on the outer surface of the "V" and deposition on the inner side due to the concept of surface growth depending on growth direction. The "V" moves away from its tip and enlarges simultaneously. Thus, increase in size and growth movement are a unified process.

The outcome of these growth processes is:

1) Enlargement in overall size of the "V"-shaped area
2) Movement of the entire "V" structure toward its own wide end
3) Continuous relocation

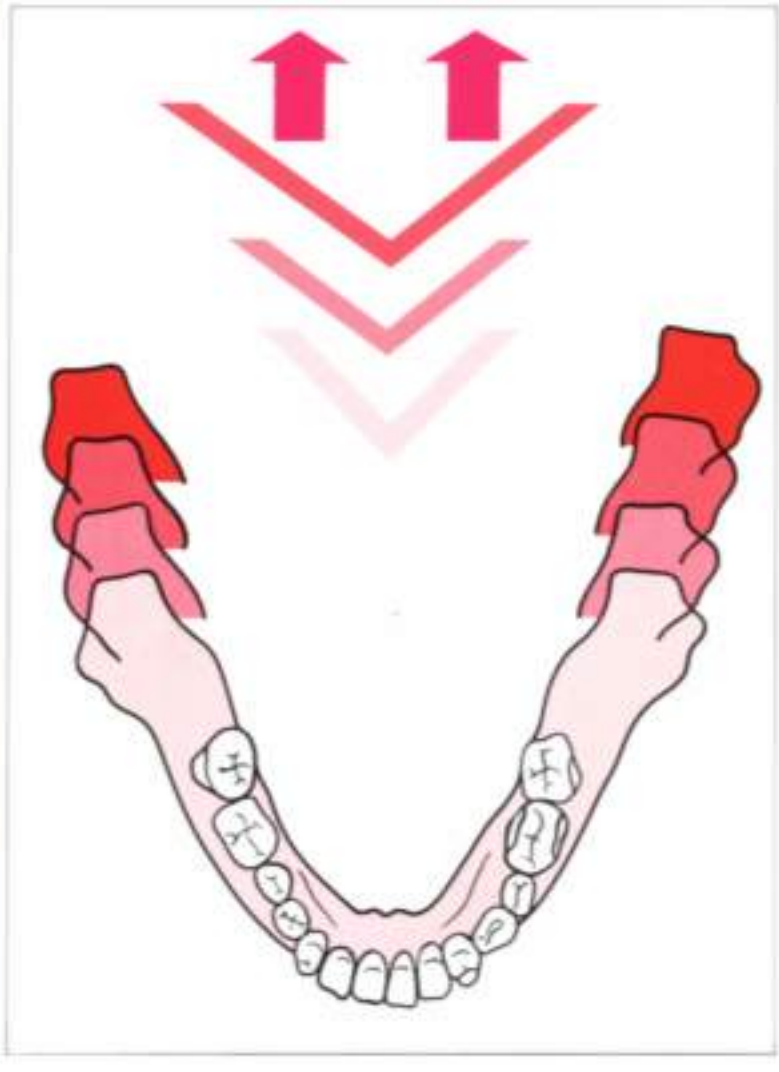




29 The "V" principle – Vertical expansion

Left: According to this growth concept, bone is deposited on the inner surface of the "V"-shaped bone and resorbed on the outer surface. Thus, the "V" moves away from its narrow end (direction of the arrow) and enlarges in overall size.

Right: Longitudinal section through the right and left coronoid processes of a mandible. The processes are enlarged during growth in accordance with the "V" principle. Bone is deposited on the lingual surfaces and resorbed from the opposing buccal surfaces. The structures increase in height, the tips of the coronoid processes diverge further, and their bony bases converge (*Enlow*, 1963).



30 The "V" principle – Horizontal expansion

The mandible viewed from above, including a horizontal section through the base of the coronoid process.

Bone is deposited on the lingual side of the mandibular structures up to the ramal surface. Thus, the coronoid processes move – despite bone deposition on the inner surfaces – in backward direction, and the posterior parts of the mandible widen (*Enlow*, 1982).

Left: Mandibular configuration of a 5-year-old and an adult viewed from above.

Surface Principle

The surface principle states that bone sides which face the direction of growth are subject to deposition and those opposed to it undergo resorption. These processes always take place on contralateral bone surfaces so that the cortical plate follows the course of growth.

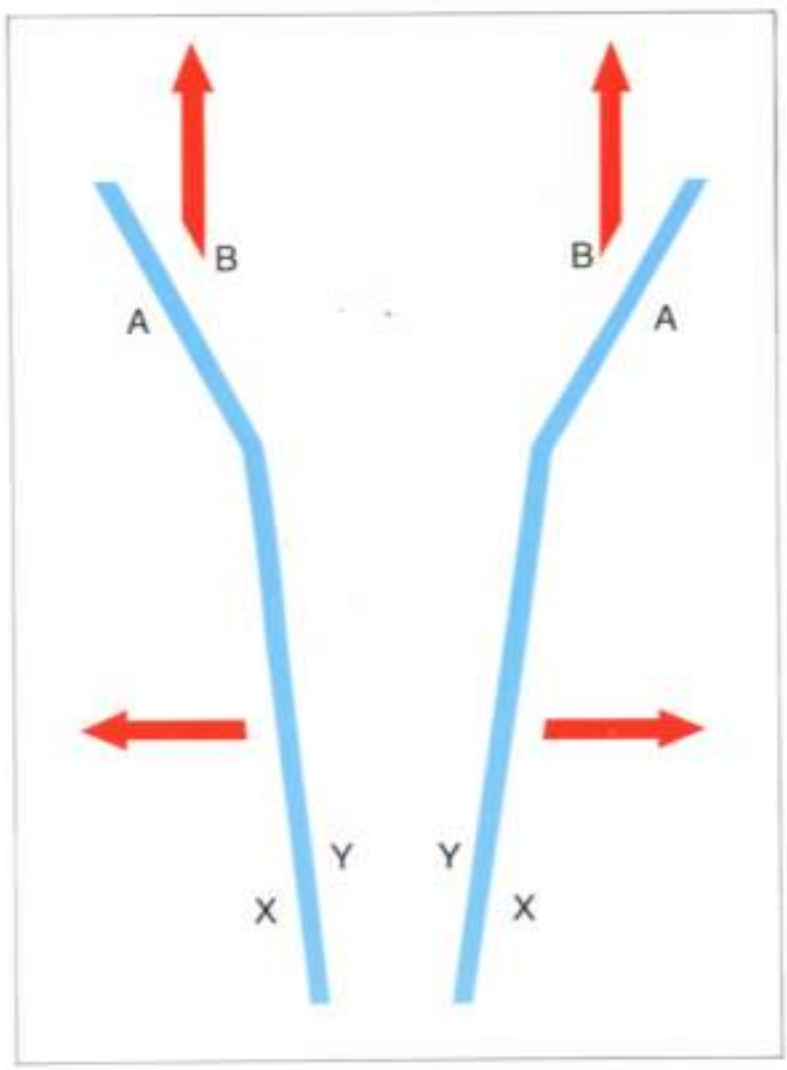
The direction of growth is not the same for all areas of the bone as each region of a structure has its own specific growth pattern. Reversals in the direction of growth can result in bone deposition and resorption processes taking place directly adjacent to one another on the same cortex.

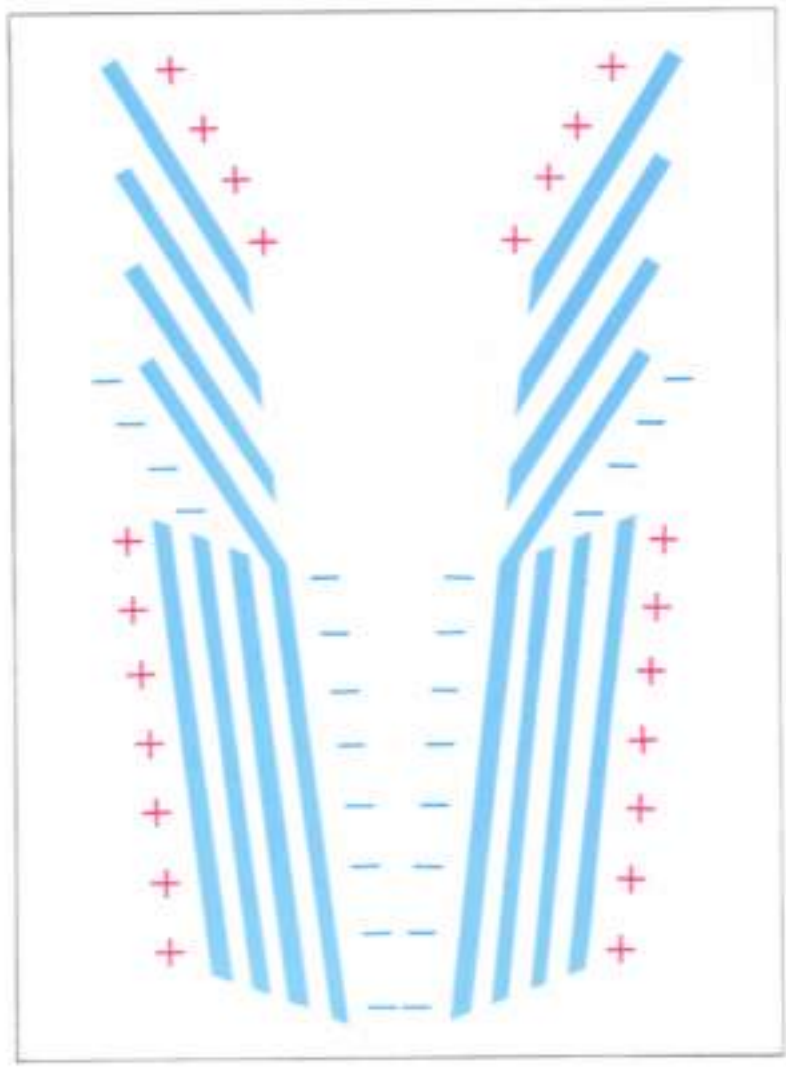
As the individual parts of the bone grow in different directions, only half of the deposition process is localized on the outer cortical plate *(periosteal bone formation)*. The other half of the growth process consists of bone deposition on the inner cortical surface *(endosteal bone formation)*.

31 Surface principle
(diagrammatic view)

\+ = Bone deposition
– = Bone resorption

The areas marked "X" on the outer surfaces of the bone and those marked "B" on the inner surfaces are in the (→) direction of growth and are depository. Accordingly, areas "A" and "Y" resorb in the opposite direction (*Enlow*, 1982).





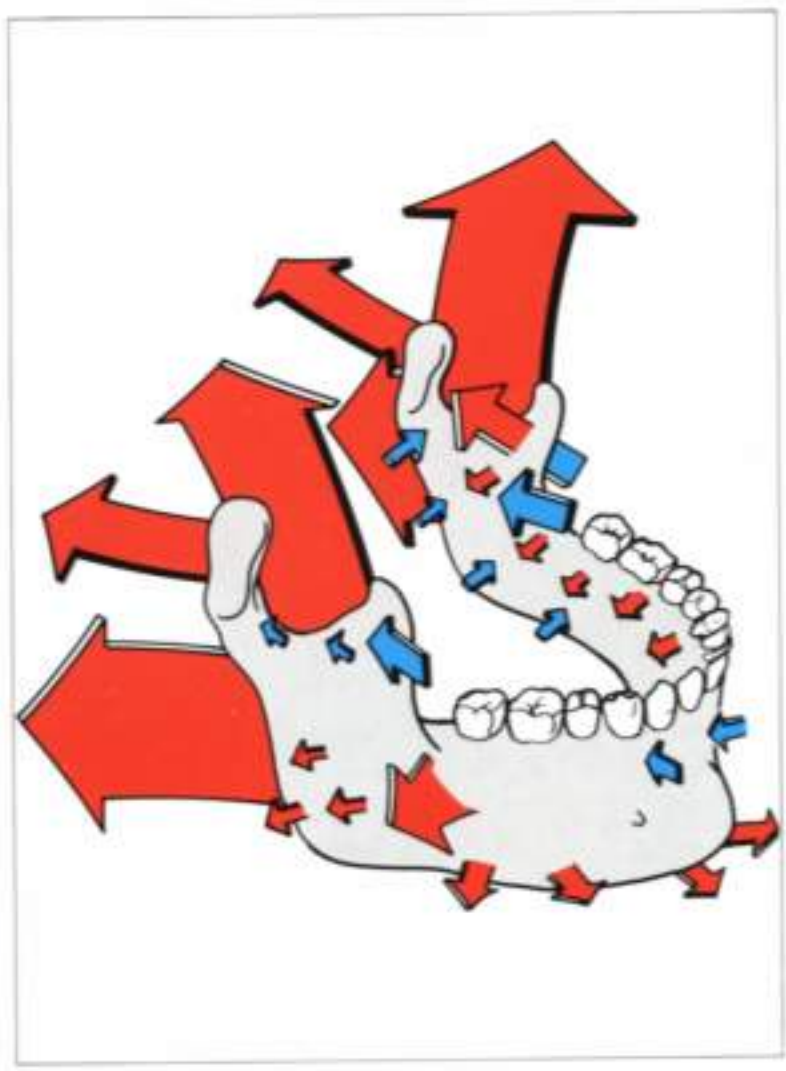
32 Direction of growth of individual areas of the mandible

Red arrow = Bone deposition
Blue arrow = Bone resorption

Right: The arrows pointing toward the bone indicate periosteal bone surfaces which do not face the direction of growth and are, therefore, resorptive. Those arrows which point away from the bone indicate periosteal surfaces which face toward the direction of growth and are depository.

The main direction of growth of the ramus and the mandibular corpus is aimed upward and backward (*Enlow*, 1982).

Left: Macerated adult mandible.



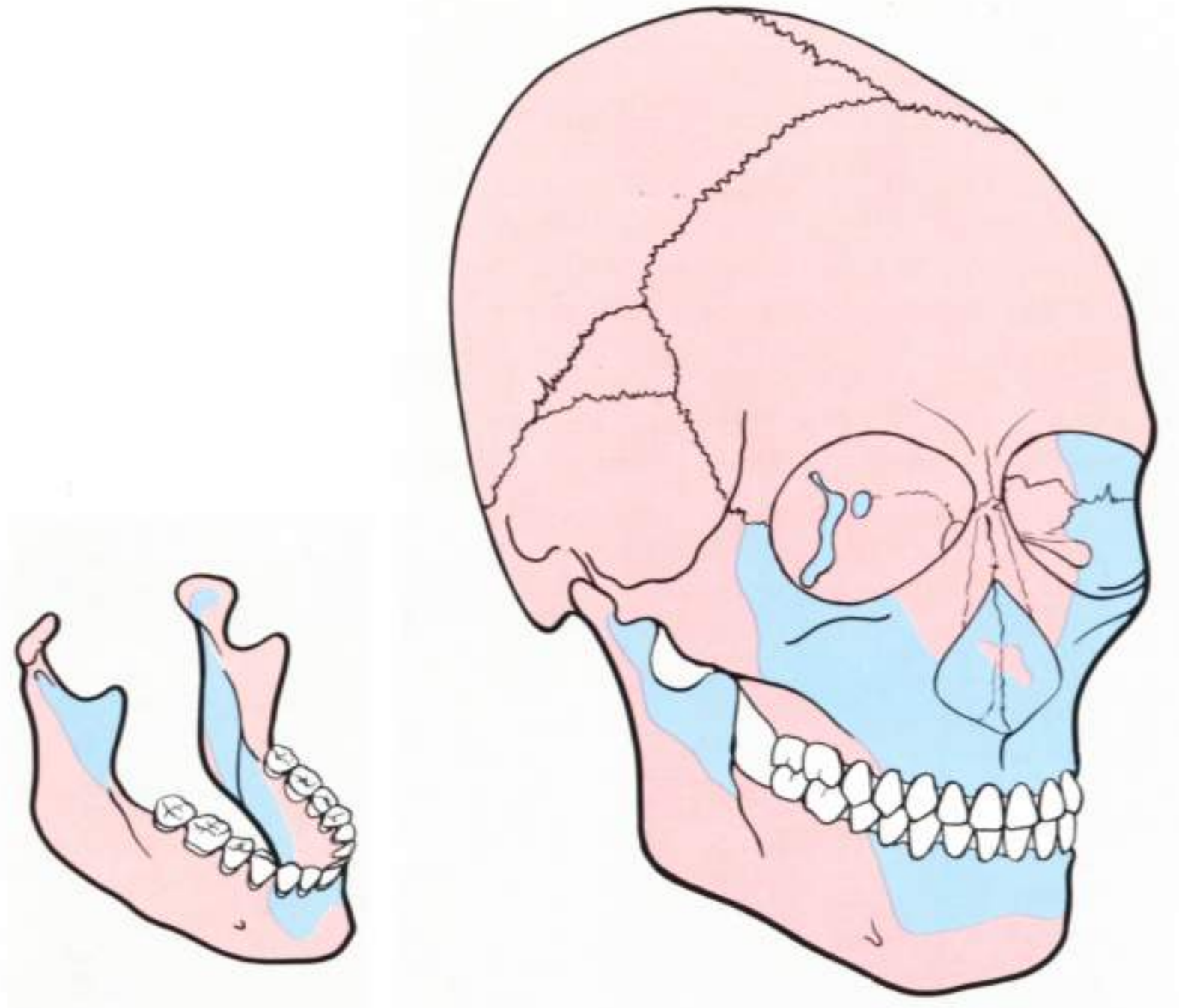
Growth Fields

Bone growth is controlled by so-called growth fields. These fields, which are distributed in a characteristic mosaic-like pattern across the surface of a given bone, have either depository or resorptive activity (Fig. 33).

If the periosteal growth field is resorptive, the opposing endosteal field is depository. On the other hand, if the endosteal surface undergoes resorption, the periosteal surface is depository. Bone growth processes, i.e. *bone drift*, are based on these periosteal/endosteal relationships.

Growth fields have a *pacemaking function*, which is controlled by the contiguous soft tissue. Each increase in length of the bone commences with the growth fields migrating within the respective connective tissue membranes (e.g. periosteum and endosteum, sutures, periodontal ligament). The enclosing soft tissues determine the changes in the underlying bone parts which are controlled by this specific growth field.

Not all growth fields of a bone exhibit the same amount of activity or velocity of growth.



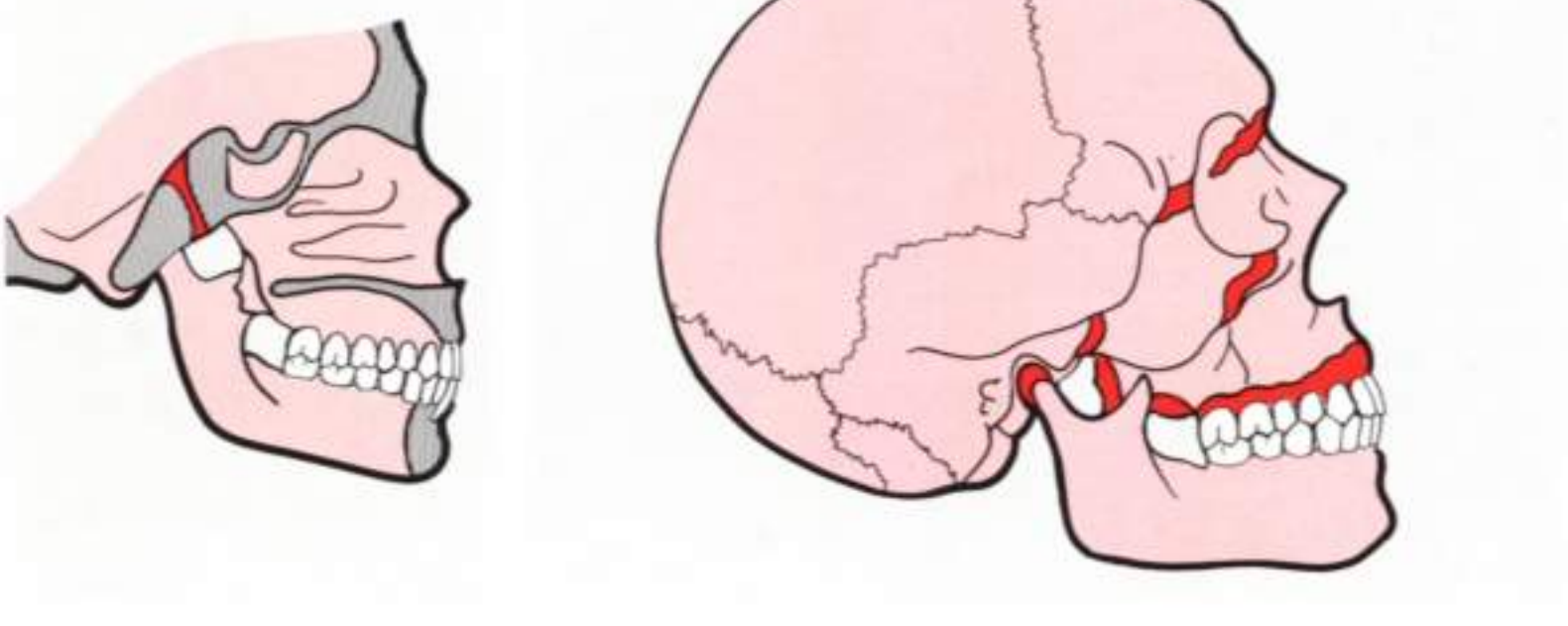
33 Arrangement of the growth fields

Red fields = Bone deposition
Blue fields = Bone resorption

Depository and resorptive fields are distributed characteristically across the entire inner and outer surfaces of the neurocranial and facial skeleton.

The activity of the growth field is not located in the bone itself. The genetic information resides within the soft tissues.

The soft tissue acts as a functional matrix to control bone growth, whereas the bone itself only reports – via a feedback mechanism which is connected to the connective tissues – when the shape, size, and biomechanical aspects coincide with the functional requirements. This information causes the histogenetic activity of the osteogenic membranes to respond (*Ten Cate*, 1980).



34 "Growth centers"

This term is often used to describe very active growth fields which are significant to the growth processes such as the cranial and facial sutures, the mandibular condyles, the maxillary tuberosities, the alveolar processes, and the synchondroses of the cranial base.

However, bone growth not only takes place in these areas. *All* inner and outer growth fields of a given bone also play an active role in the process (*Enlow*, 1982).

Displacement

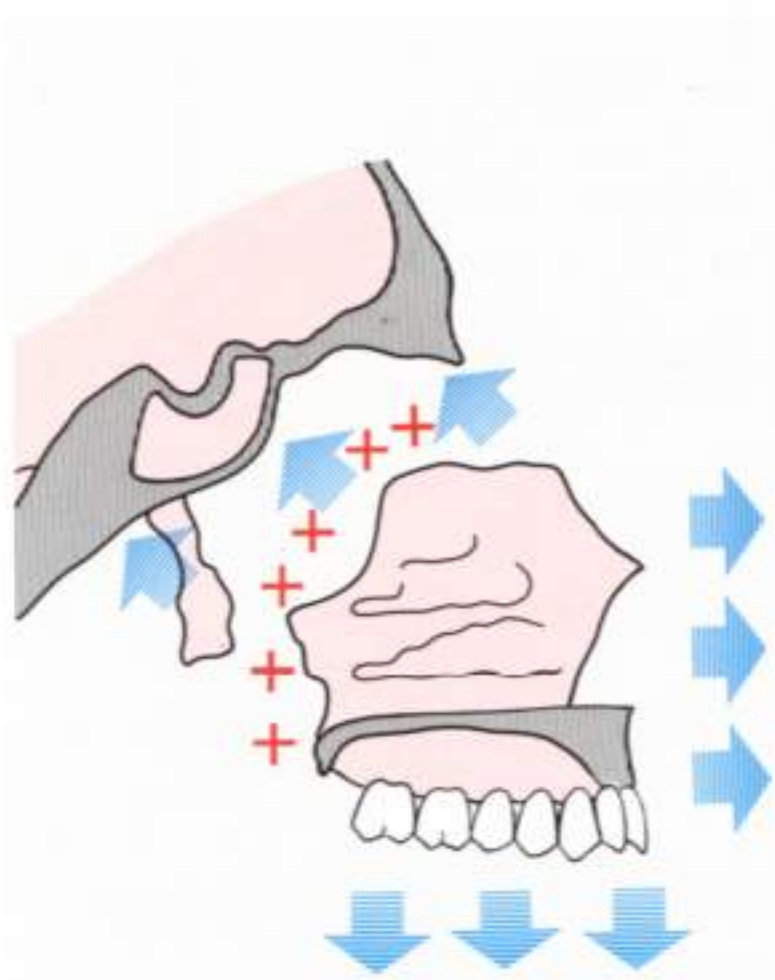
Apart from direct bone growth due to deposition and resorption, the process of displacement, i.e. the translatory movement of the whole bone caused by the surrounding physical forces, is the second characteristic mechanism of skull growth. The entire bone is carried away from its articular interfaces (sutures, synchondroses, condyles) with adjacent bones.

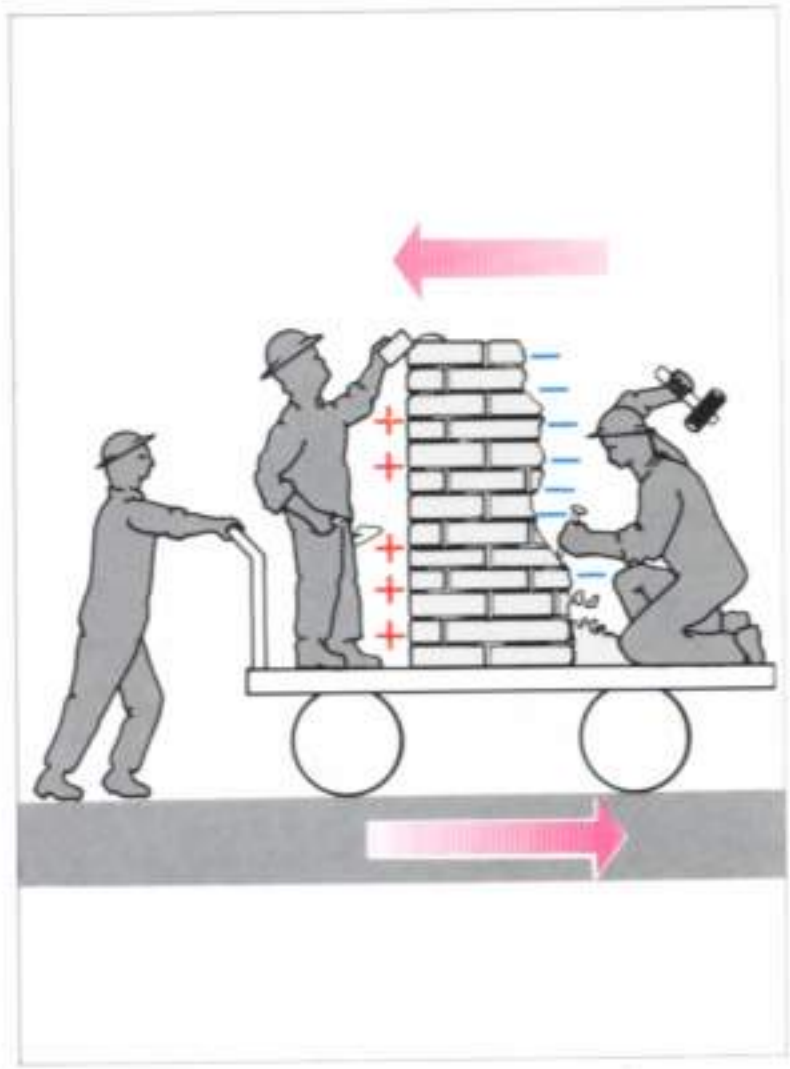
Displacement in conjunction with bone's own growth is termed *"primary displacement"* by Enlow. Displacement is initiated by the sum of the expansive forces of the soft tissues in the growing face. It occurs parallel to bone growth, thus creating a space around the contact surfaces into which the bone can enlarge. The degree of displacement exactly equals the amount of new bone deposition, although the direction of displacement is always opposite to that of the bone deposition.

Bone displacement due to the enlargement of bones and soft tissue which are nearby or not immediately adjacent is termed *"secondary displacement."*

35 Primary displacement of the nasomaxillary complex
The bone structure grows upward and backward (⇳) due to deposition and resorption processes. Simultaneously, the entire complex is displaced forward (⇳). Thus, the necessary space for bone deposition is created around the articular surfaces. Primary displacement always takes place in the opposite direction to the vector of the bone growth.

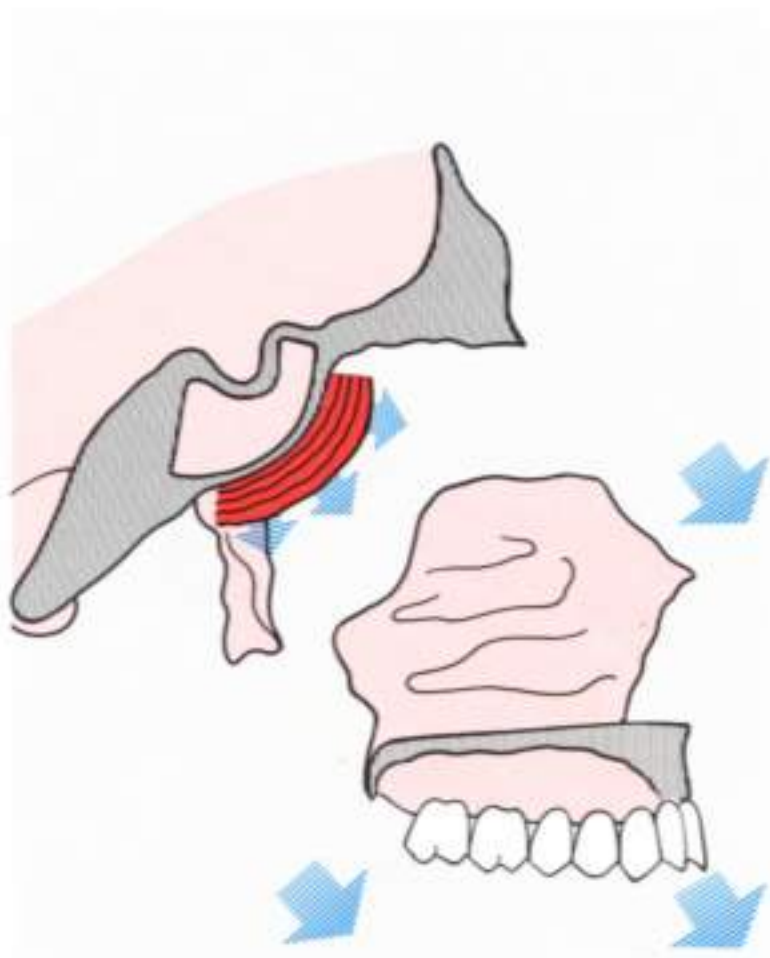
Right: Diagrammatic view of the events during primary displacement. The bone is remodeled and shifted in the opposite direction simultaneously (*Enlow*, 1982).

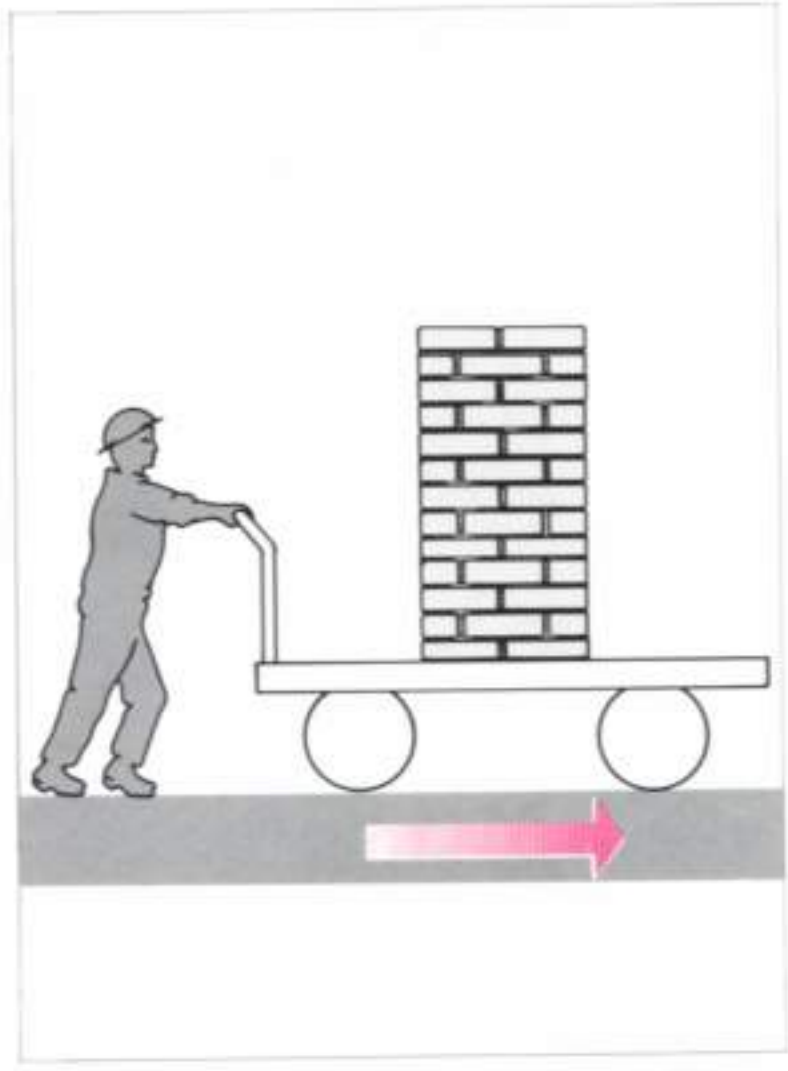




36 Secondary displacement of the nasomaxillary complex
This process is not associated with growth of the bone itself. This type of displacement is initiated by enlargement of adjacent or remote bones and soft tissues. Its effect is transferred from bone to bone and develops in relatively distant areas. Secondary displacement of the nasomaxillary complex is caused by growth of the middle cranial fossa and the temporal lobe, and is directed forward and downward (⇳).

Right: Diagrammatic view of secondary displacement. The bone is carried away without being remodeled (*Enlow*, 1982).





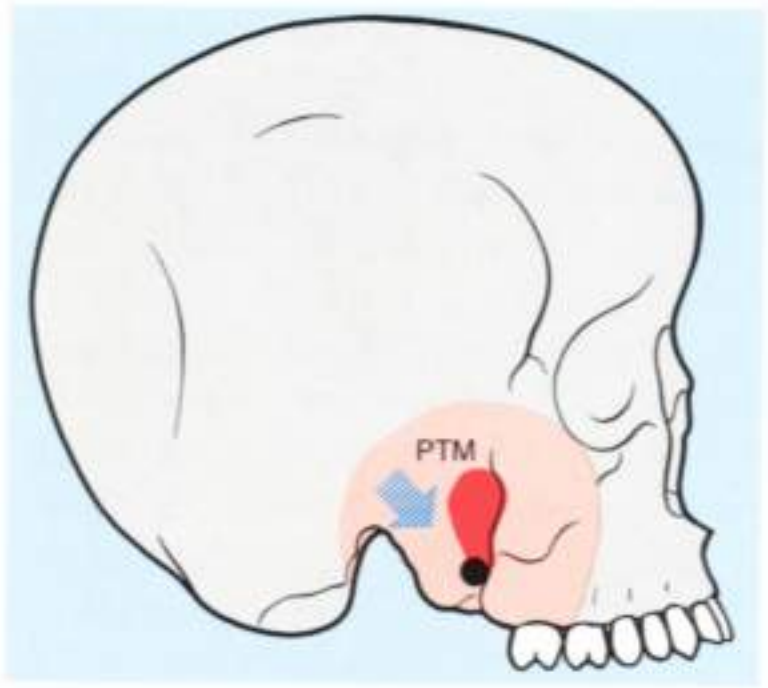
Growth Processes

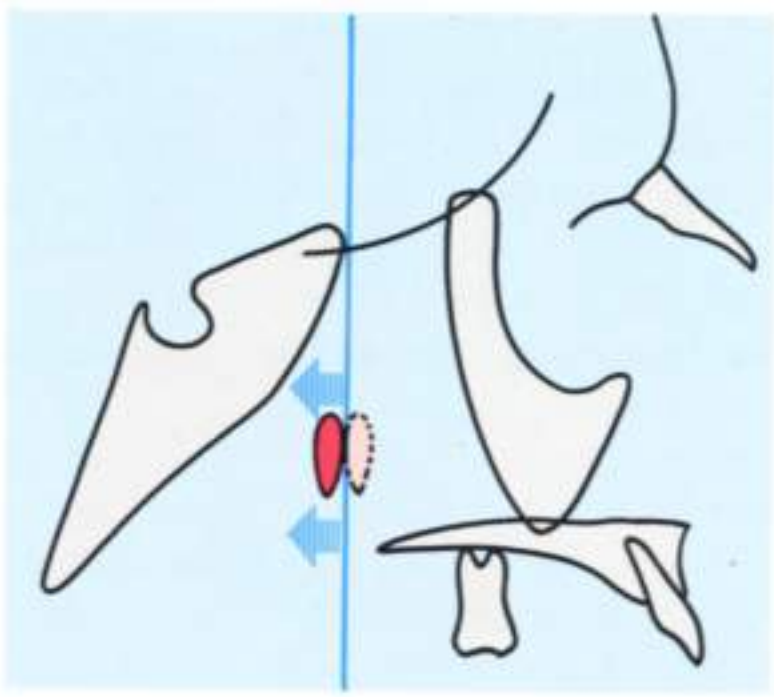
Maxillary Growth

Maxillary *remodeling* involves bone deposition on the posterior wall of the maxillary tuberosity, resulting in a posterior lengthening of the bony maxillary arch. Deposition on the outer surfaces of the tuberosities and resorption on the inner surfaces causes the cortical plate to drift in a backward direction and the space for the pneumatic cavities enlarges (Fig. 37).

This posterior elongation of the upper jaw is coupled with *primary displacement* of the maxilla which is directed anteriorly and exactly equals the amount of posterior lengthening (Fig. 38). This increase in overall length of the maxilla creates tensile forces which initiate tensile adaptive sutural growth.

Due to growth of the middle cranial fossa, the maxilla, the anterior cranial base, the forehead, and the zygoma are shifted in a forward direction. This process leads to *secondary displacement* of the maxilla, i.e. it is displaced passively due to expansion of the middle cranial fossa without the growth processes of the maxilla itself being directly involved. The extent of secondary displacement corresponds to the degree of anterior extension of the middle cranial fossa (Fig. 38).

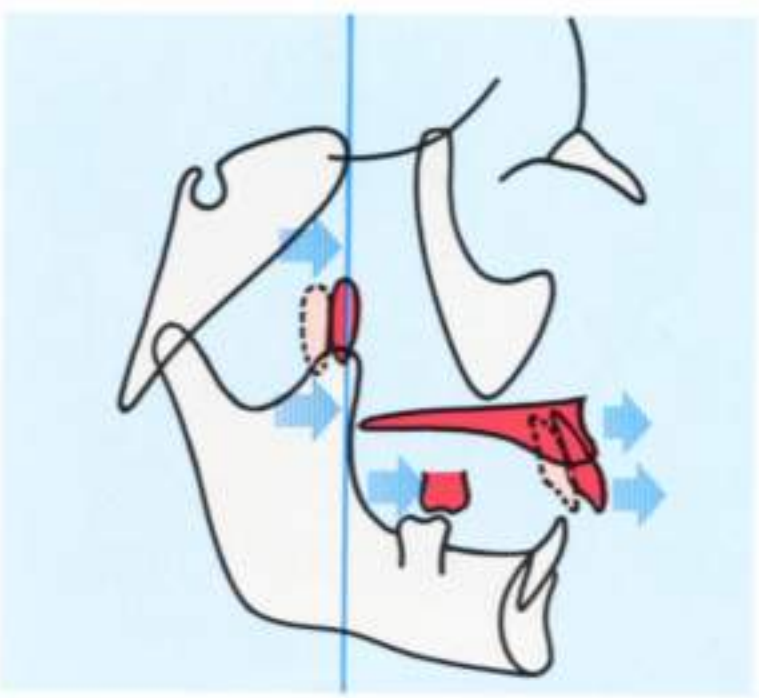


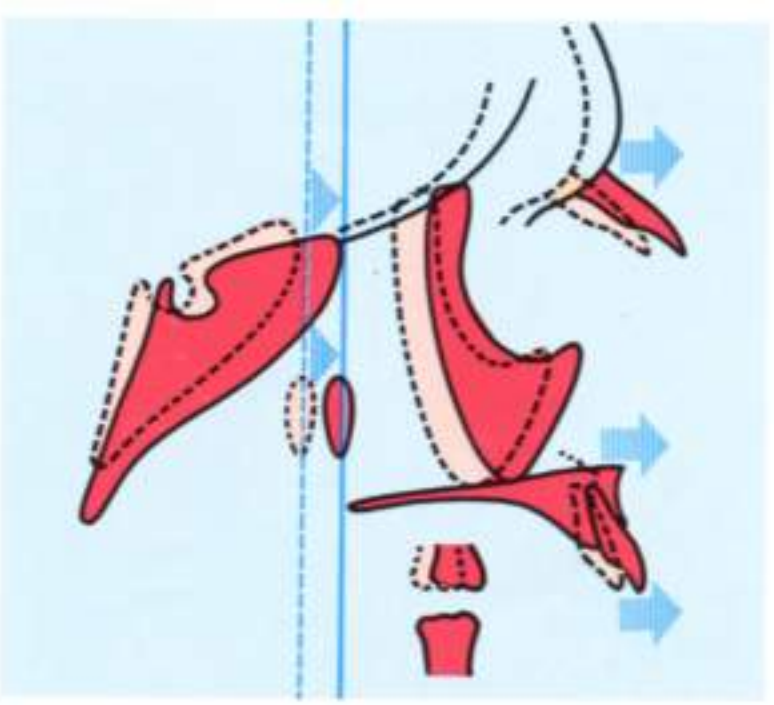


37 Remodeling of the upper arch

The upper jaw is extended posteriorly by means of bone deposition on the outer cortical surface of the maxillary tuberosity and resorption on the inner plate. This causes the pterygopalatine fossa and the pterygomaxillary fissure (PTM) to move posteriorly (the pterygomaxillary fissure is illustrated as an inverted teardrop, as on a cephalogram).

Left: The pterygopalatine fossa is positioned between the pterygoid plates and the maxillary tuberosity (*Enlow*, 1982).





38 Primary and secondary displacement of the maxilla

Vertical plane of reference = PTM line
Horizontal plane of reference = Functional occlusal plane

Left: The maxilla increases in length and is displaced anteriorly simultaneously (primary displacement). Both changes take place to the same amount.

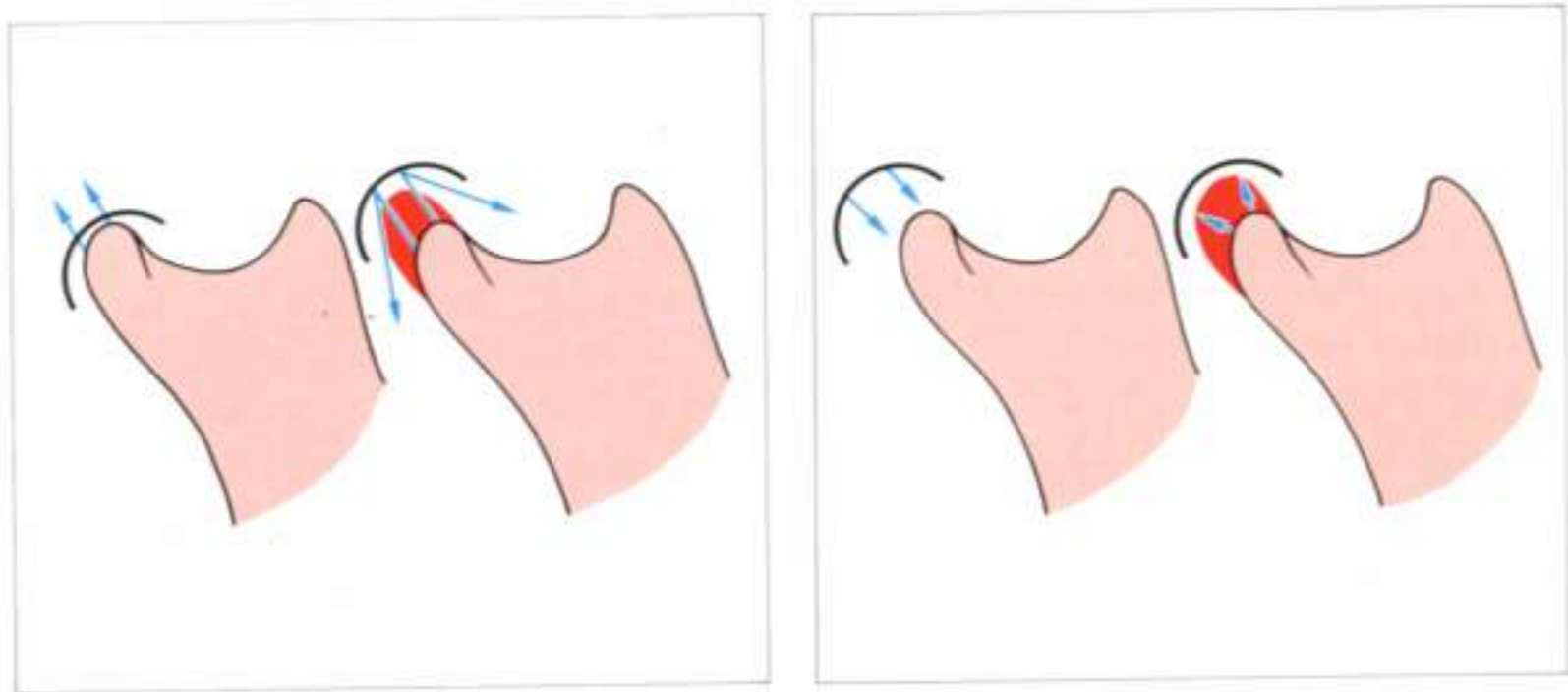
Right: Secondary displacement of the maxilla results from enlargement of the middle cranial fossa.

Mandibular Growth

Contrary to previous assumptions, the condyles do not govern the growth of the entire mandible. They are not a type of "control center" with direct control over the growth fields, and function only locally. The significance of the condylar cartilage layer is that, due to its articular junction with the basicranium, compressive forces are created, and cartilage is a type of tissue which adapts to pressure (Fig. 39).

Downward and forward displacement of the mandible is an important aspect in the growth processes. Previous theorists claimed that the pressure exerted on the glenoid cavity by the growing condyle caused displacement of the mandible out of articular contact (Fig. 39). Experiments have shown that, even after both condyles have been removed, the mandible can assume a relatively normal position. These experiments indicate that:

1) condylar growth is largely irrelevant to the growth of the other mandibular structures; 2) mandibular displacement, which depends on growth, sets in without a "push" of the condyles against the cranial base.



39 Mandibular displacement
It was previously believed that growth of the condylar cartilage was the cause of mandibular displacement.

Right: According to other growth theories, mandibular displacement is the primary process and results from enlargement of the soft tissues.

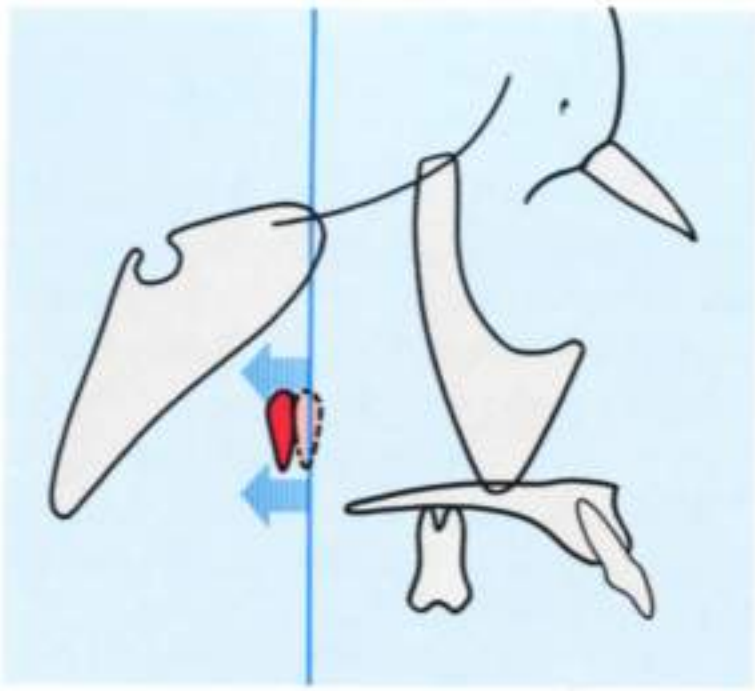
Condylar growth is secondary and adaptive, and reestablishes the relationship of the displaced mandible in the temperomandibular joint (*Enlow*, 1982).

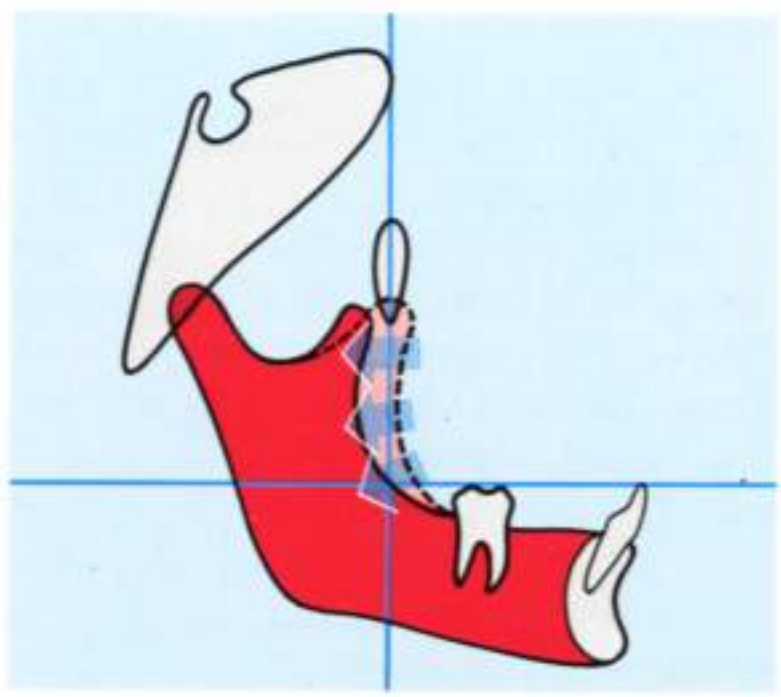
When assessing mandibular growth, the horizontal and ascending sections must be considered separately as, according to the Hunter-Enlow law, the individual structures should each be given a different growth equivalent.

The *maxillary arch* is the specific strutural counterpart of the mandibular corpus, i.e. during remodeling the horizontal section of the mandible is elongated posteriorly by the same amount as the maxilla.

Elongation of the mandible toward the ramus is possible because the anterior surface of the ramus is remodeled by resorption into the elongated mandibular corpus (Fig. 40). Simultaneously, the entire mandible is displaced anteriorly by an amount that equals the maxillary displacement (primary displacement). The posterior sections of the ramus and the condyles grow posteriorly, i.e. diagonally upward and backward, and increase in height, keeping pace with the mandibular displacement. By this means, the mandible is not only displaced forward but also downward (Fig. 41).

Growth of the *middle cranial base* also leads to secondary mandibular displacement, similar to that of the maxilla (Fig. 42). As the expansion of the middle cranial fossa is largely directed forward, i.e. the enlargement is localized anterior to the condyle and ramus, secondary displacement does not carry the mandible as far forward as the maxilla. This imbalance is made up for by the horizontal growth of the ramus, which leads to the correct anatomical relationship between the maxillary and mandibular arch (Fig. 43). Thus, the ramus is considered the growth equivalent of the middle cranial fossa.

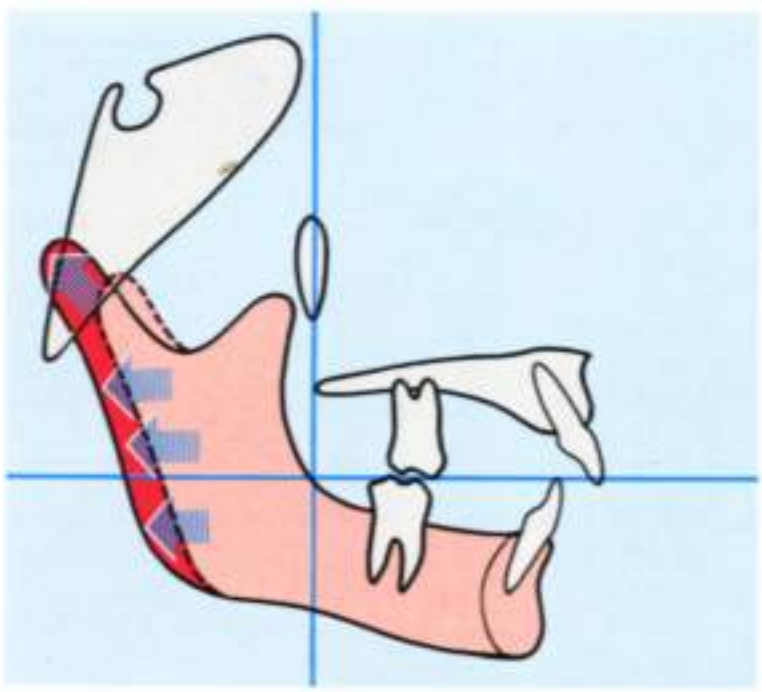


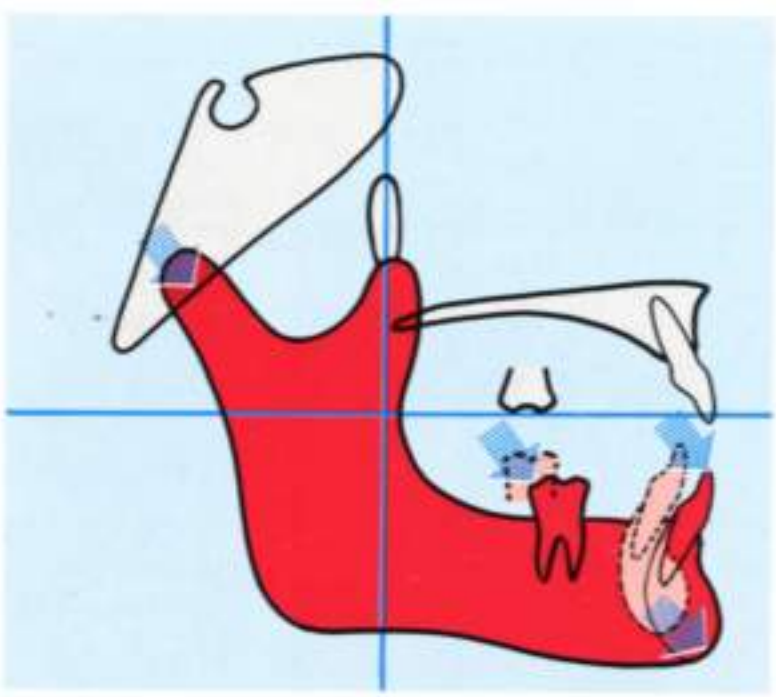


40 Remodeling of the mandible

The body of the mandible elongates posteriorly due to resorption and remodeling of the anterior border of the ramus.

Left: The mandibular corpus lengthens by an amount that equals the enlargement of the maxillary arch, which is its structural counterpart (Enlow, 1982).

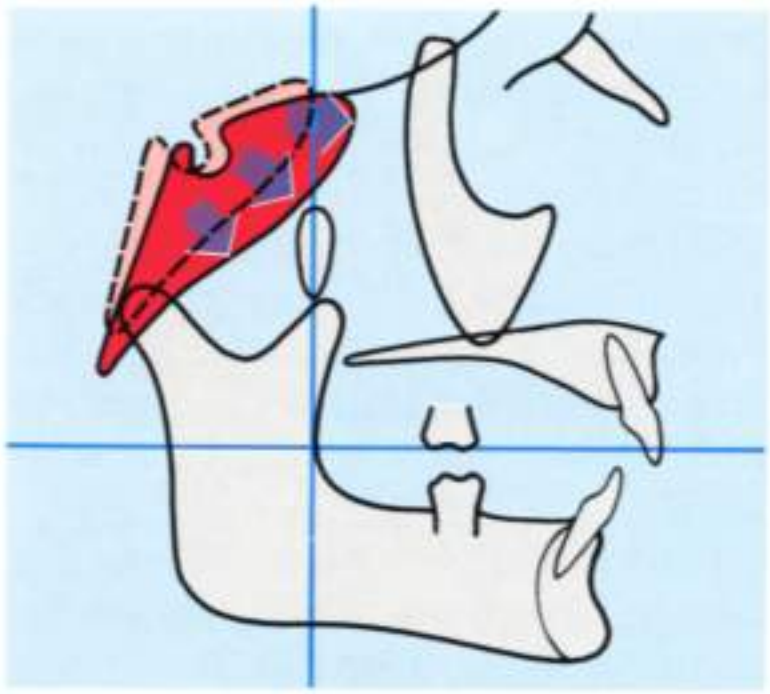


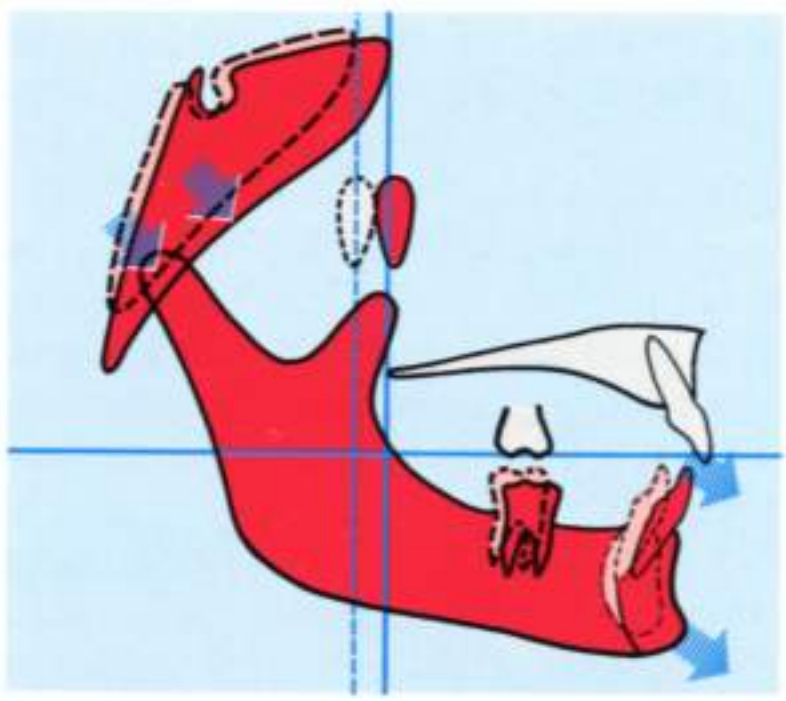


41 Primary displacement of the mandible

Right: Elongation of the mandibular corpus and anterior displacement of the mandible take place simultaneously.

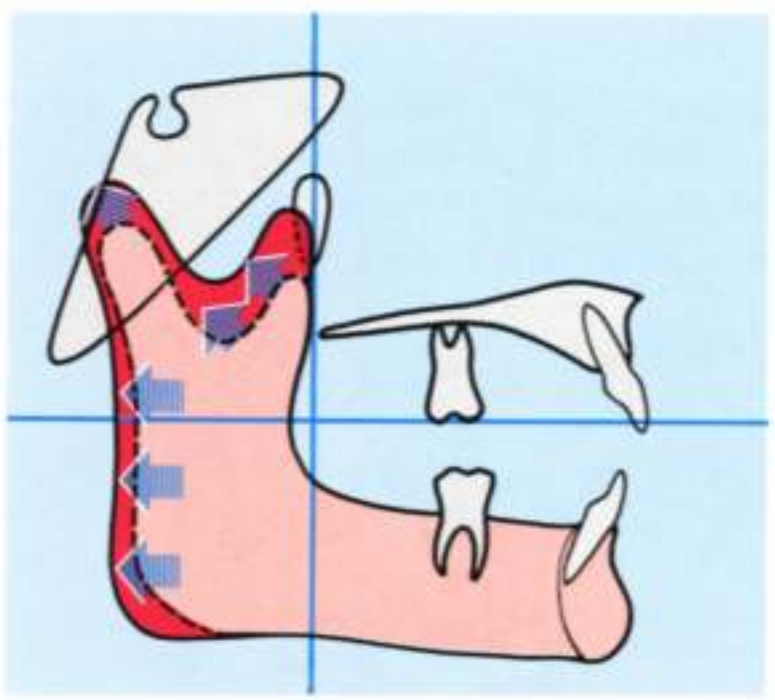
Left: This process is stimulated by the posterior growth of the condyles and the posterior borders of the ramus. The ramus regains its original width by means of bone deposition as the posterior depository and the anterior resorptive activity are precisely equal (Fig. 40).

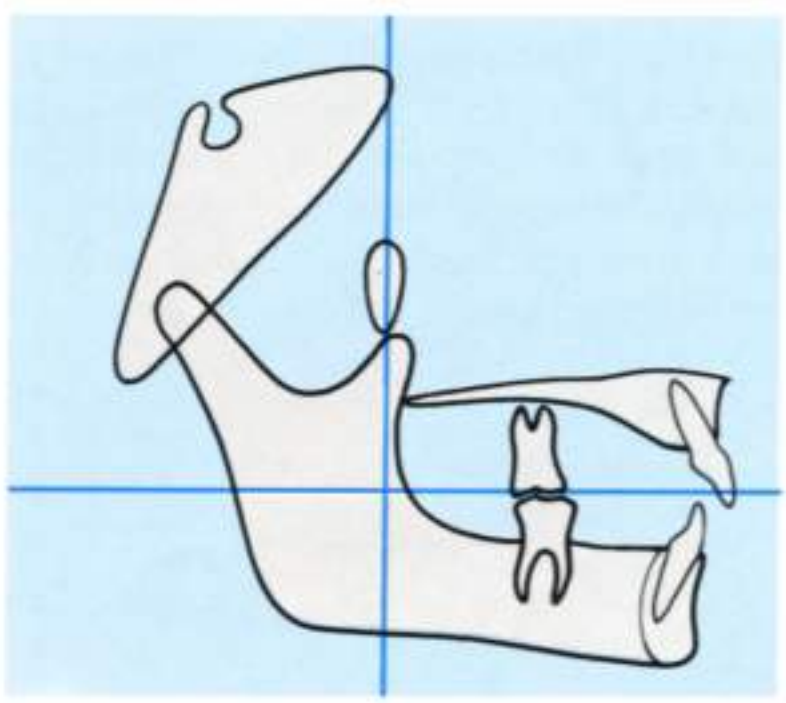




42 Secondary displacement of the mandible

Left: The mandible is displaced forward and downward by the enlargement of the middle cranial base. As the middle cranial fossa growth is mostly localized anterior to the condyles, secondary displacement of the mandible is not as pronounced as that of the maxilla (Fig. 38). Thus, this phase ends – despite both structures having been elongated by the same amount – with a maxillomandibular Class II relationship.





43 Horizontal growth of the ramus

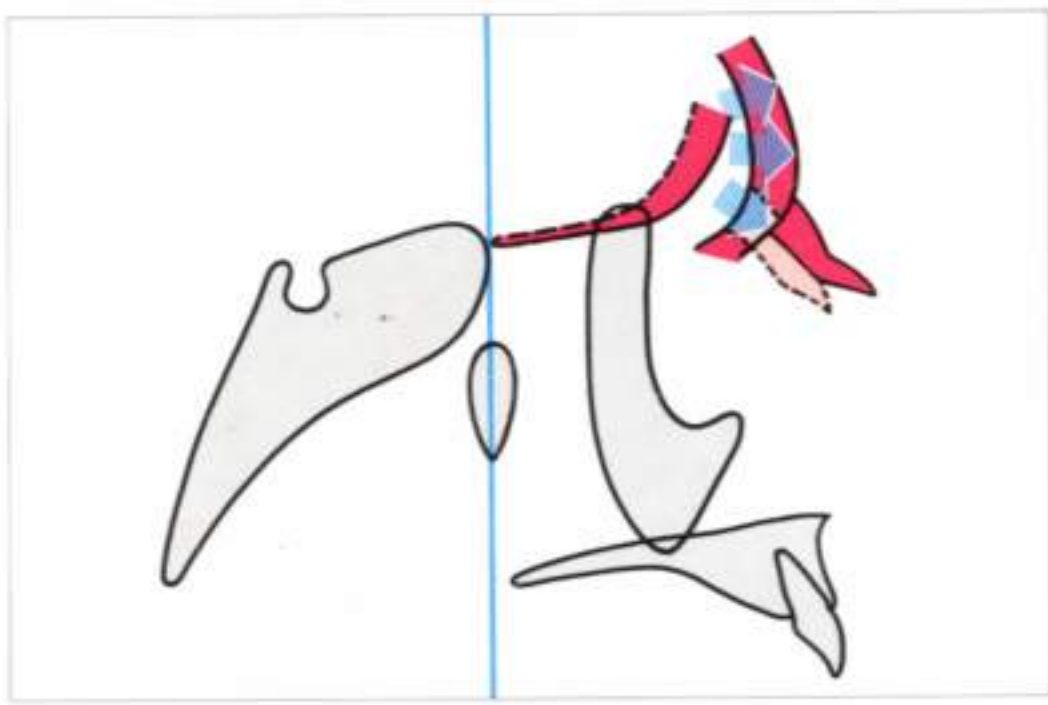
The ramus, which is the specific structural growth equivalent of the middle cranial fossa, is displaced posteriorly until its horizontal dimension corresponds to those of the middle cranial fossa. The simultaneous condylar growth, which takes place diagonally upward and backward, causes anterior displacement of the mandible at the same time.

Right: This compensates for the sagittal discrepancy between the upper and lower jaws and displaces the occlusal plane inferiorly.

Growth of the Midface

The horizontal growth of the midface is determined by the expansion of the anterior cranial fossa, which enlarges anteriorly to an extent that matches the sagittal development of its growth equivalent, i.e. the maxilla (Fig. 44). The resorption and deposition processes on the endocranial and ectocranial surfaces lead to displacement and remodeling of the underlying structures (nasal bone, ethmoid bone). Thus, the horizontal development of the midface is balanced inferiorly with the anteroposterior elongation of the maxilla and superiorly with the horizontal extension of the anterior cranial fossa.

During *vertical displacement* of the midface, the maxillary arch is displaced in a downward direction due to resorption on its nasal surface and simultaneous, deposition on its palatal surface (Fig. 45). Thus, space is created for the sinuses to expand. Their inner surfaces are largely resorptive. Unlike other primates, the anterior part of the human maxilla is resorptive, and the premaxilla grows straight downward and does not move forward (Fig. 45).



44 Sagittal development of the midface
Expansion of the frontal lobes causes elongation of the anterior cranial base and displaces the midface forward.

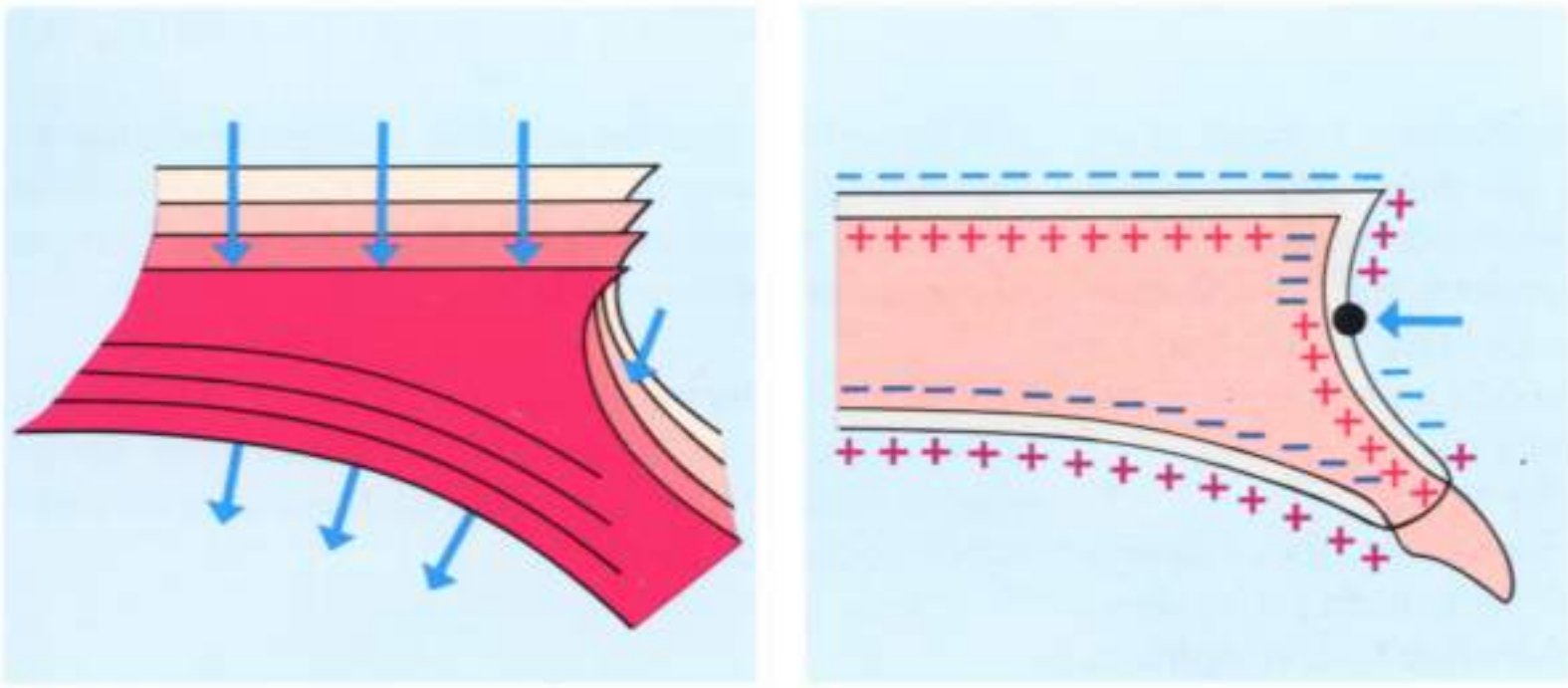
The increase in length of the anterior cranial fossa corresponds to the sagittal development of the maxillary arch, which is its structural counterpart.

Apart from these remodeling processes, the vertical development of the maxilla is also associated with its primary displacement (Fig. 46), the latter triggering an equivalent amount of secondary sutural bone deposition (Fig. 46). The downward movement of the maxilla is usually not parallel, but differs anteroposteriorly. This applies to both the remodeling process and the displacement. The result is a *rotational movement of the maxilla,* which can be compensated or increased by the sum of variations in both growth mechanisms (Fig. 46).

Due to active apposition and resorption processes in the bony alveolar sockets (Fig. 47), vertical drift of the *upper teeth* sets in simultaneously to maxillary remodeling. Further lowering of the upper dentition results from displacement of the maxilla (Fig. 47). This type of downward movement of the dental arch can, above all, be influenced by *therapeutic means.* The structural counterpart for the downward growth of the nasomaxillary complex is the vertical enlargement of the ramus and middle cranial base, as these growth processes displace the mandible inferiorly (Fig. 42). Once the upper teeth have moved into place, an upward drift of the lower teeth and their alveolar processes commences, thus establishing the final occlusion (Fig. 48). As the vertical movement of the teeth is physiologically greater in the maxilla than in the mandible, the orthodontic therapeutic possibilities are also greater in the maxillary arch.

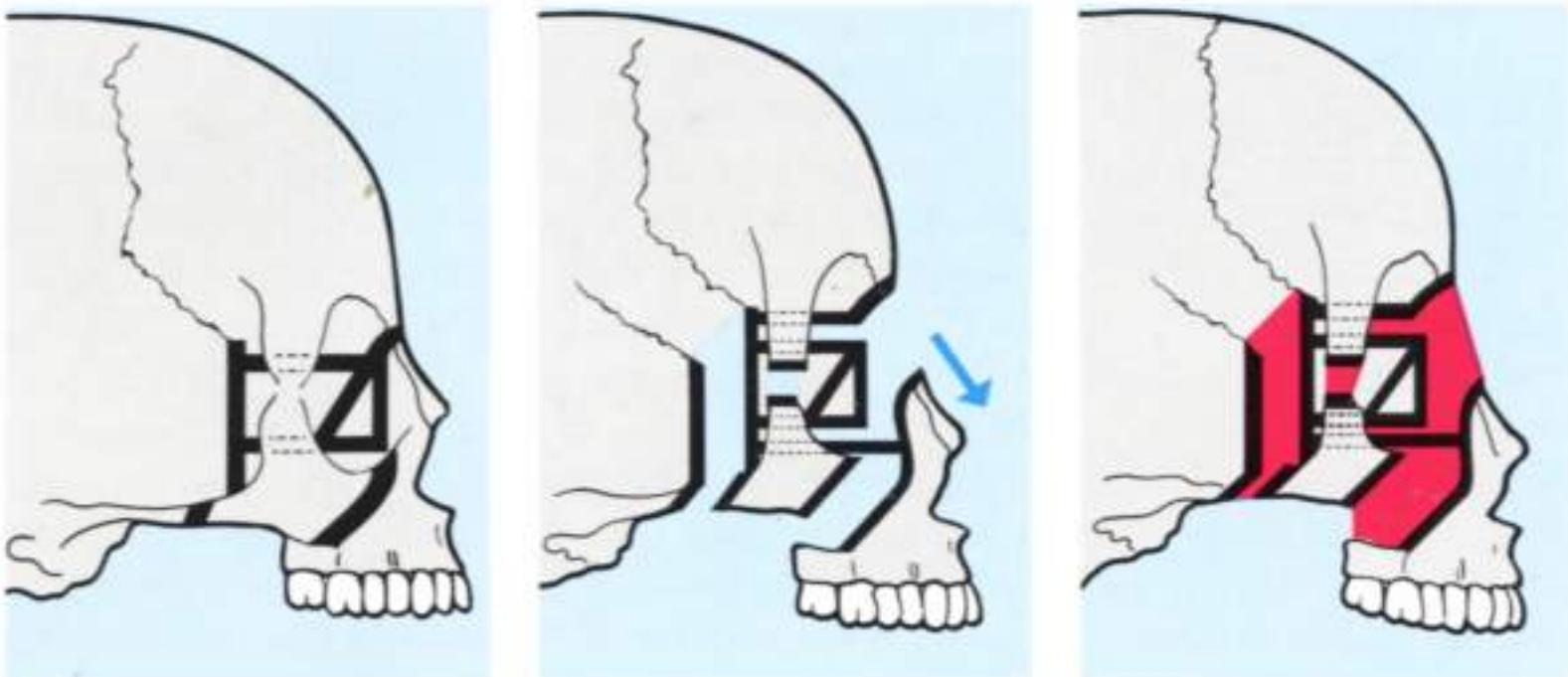
Simultaneous to the drift of the lower teeth, remodeling takes place around the chin, the mandibular corpus, the lower incisors, and their alveolar processes. The incisors rotate lingually and move posteriorly to establish the proper overbite.

Resorption on the outer surface of the anterior alveolar region and bone deposition on the anterior and inferior external contours of the symphysis cause the chin to become more prominent (Fig. 48).



45 Bone enlargement
The bones of the midface are enlarged and displaced simultaneously. Deposition on the oral cortical plate and resorption on the nasal cortical surface cause the palate and premaxilla to grow downward.

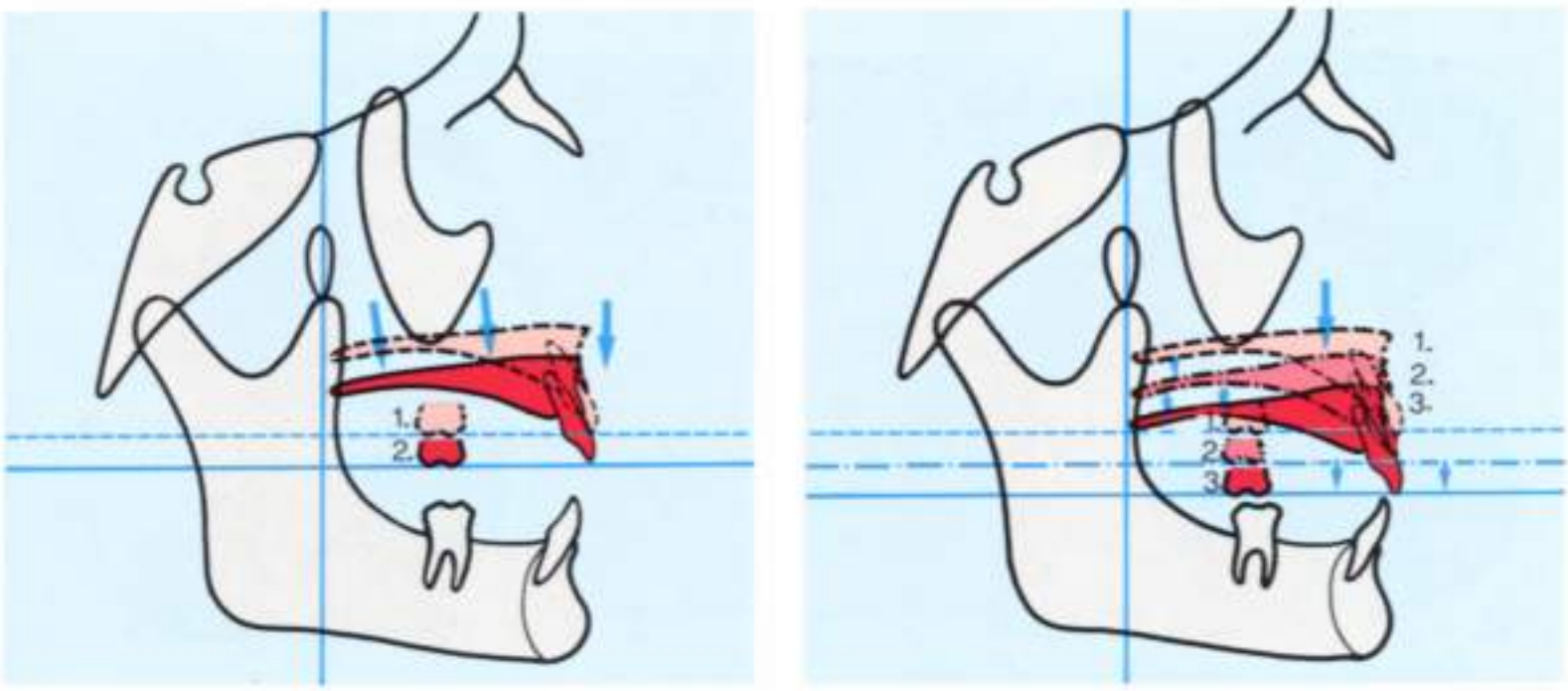
Right: Reversal line (⇨) on the concave labial surface of the premaxilla. The surface beneath the vertex is resorptive (–). Thus, the anterior part of the maxilla moves inferiorly with the palatal vault.



46 Primary displacement of the midface
According to Enlow, the nasomaxillary complex is displaced in an inferior direction due to enlargement of the contiguous soft tissue.

Center: The changed tension effect on the facial sutures leads secondarily to sutural bone deposition.

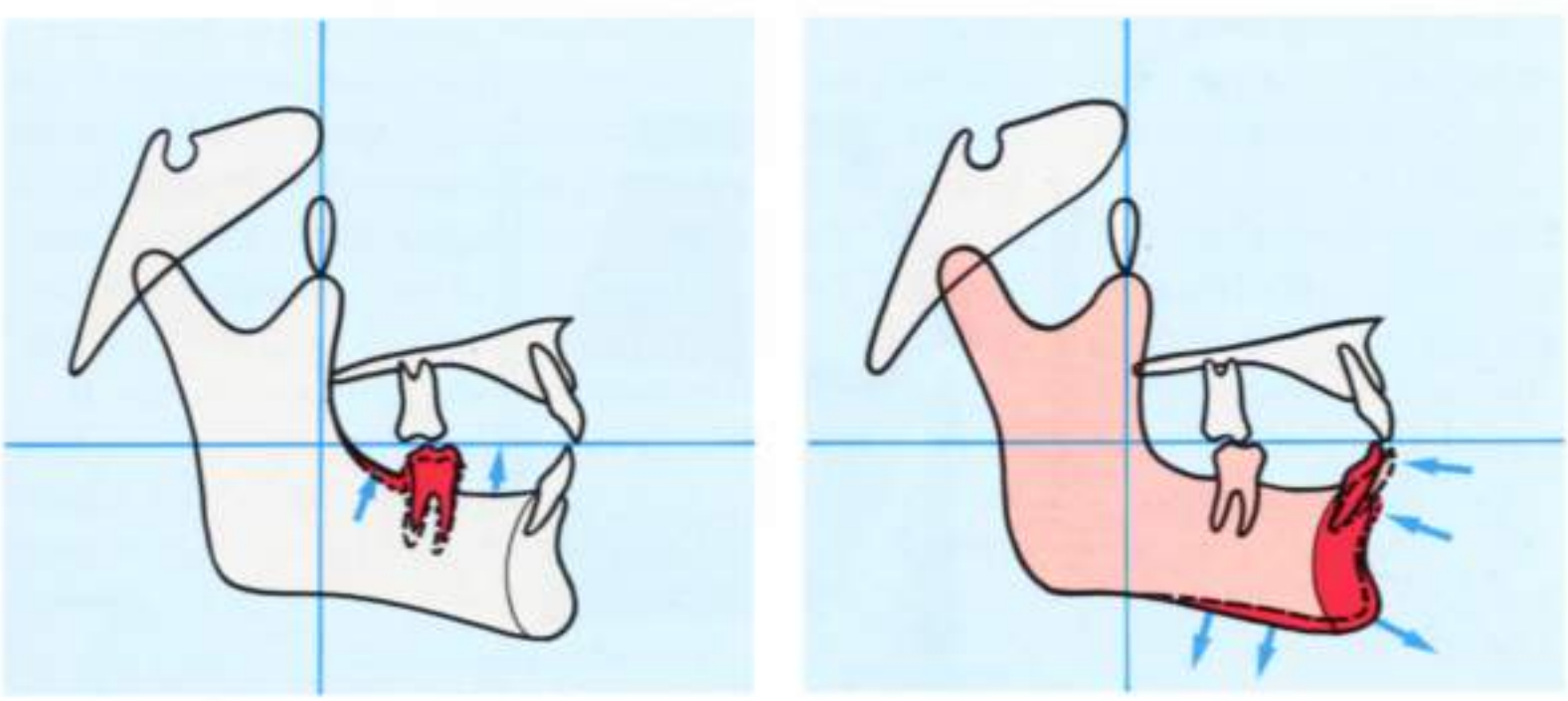
Right: Thus, the continuous sutural contact is maintained (*Enlow*, 1982).



47 Tooth drift
Displacement of the nasomaxillary complex causes the upper teeth to drift passively from position 1) to 2).

Right: Simultaneously, the teeth drift actively from position 2) to 3) due to bony remodeling of their alveolar sockets.

This process takes place parallel to the remodeling process of the hard palate and premaxilla.



48 Occlusal adjustment
The lower teeth drift, together with their alveolar bone, in an upward direction, thus establishing the occlusion.

The lower incisors and their alveolar process move lingually due to remodeling growth. At the same time, new bone is deposited around the chin.

Growth Equivalents

The Hunter-Enlow growth equivalents concept is an important principle covering the development of the facial skeleton. As the individual components of the skull develop in different directions, they must interreact directly, in order to compensate for the various growth activities. This is achieved by growth equivalents which act in opposing directions.

These growth equivalents coordinate the different movements of the cranial base, the nasomaxillary complex, and the mandible, which are due to development, and thus determine the adaptive changes in relation to the individual parts of the skull. For example, elongation of the anterior cranial base is related with enlargement of the nasomaxillary complex.

Disturbances during realization of this growth pattern cause *craniofacial anomalies*. The disturbance can be related to disproportions of the equivalents in the vertical or horizontal plane.

49 Growth equivalents according to Hunter and Enlow

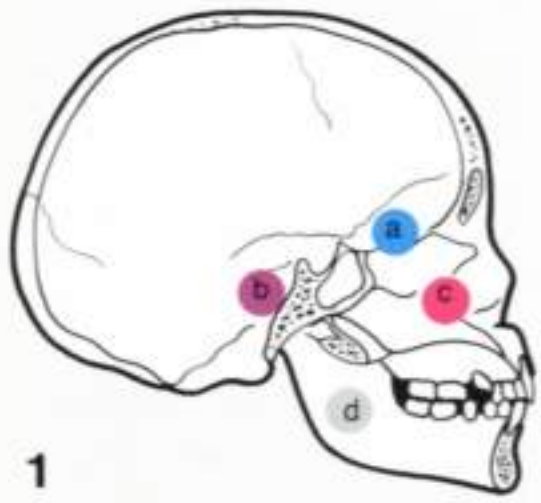
1 The anterior cranial base (a), the spheno-occipital complex (b), the nasomaxillary complex (c) and the mandible (d) are among the individual components of the skull.

2 Elongation of the anterior cranial base (x) is associated with corresponding enlargement of the nasomaxillary complex. The latter grows in posterior direction (g) and is displaced anteriorly (f) at the same time.

3 The growth of the spheno-occipital synchondrosis (m, k) constitutes the growth equivalent for the nasopharynx (p) and the ramus of the mandible (d). The ramus grows in a posterior direction (g) and the entire mandible shifts forward (z). This process compensates for the sagittal relationship of the mandibular arch to the protruding nasomaxillary complex.

4 The vertical lengthening of the clivus and the ramus (b and d) forms the growth equivalent for the vertical development of the nasomaxillary complex (c).

The last-mentioned process is based on nasal (na) and maxilloalveolar (av) growth. The ramus grows posteriorly and upward (g) and moves downward with compensatory condylar growth. (y) (*Graber*, 1972).



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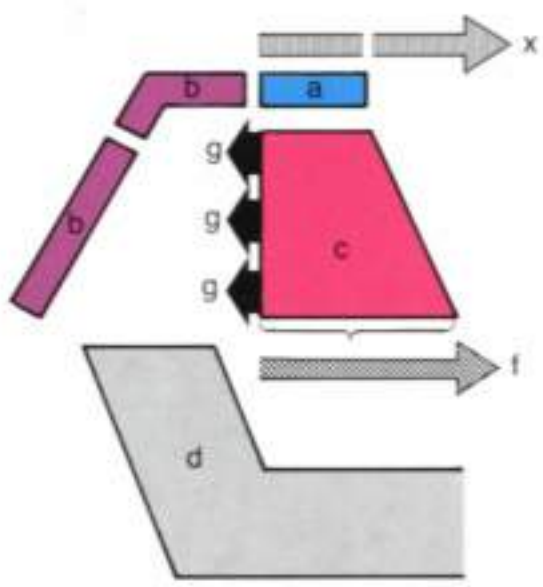

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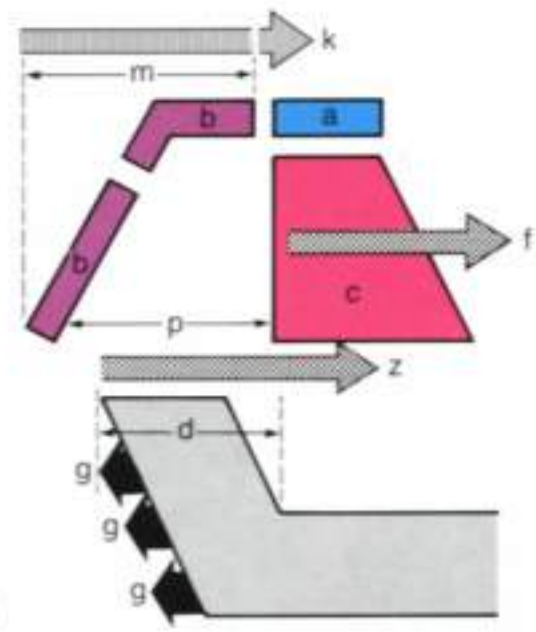

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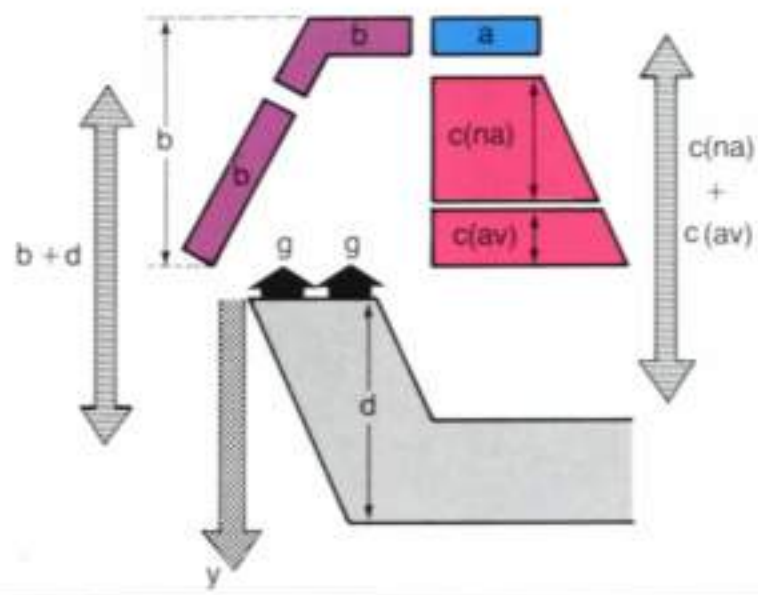
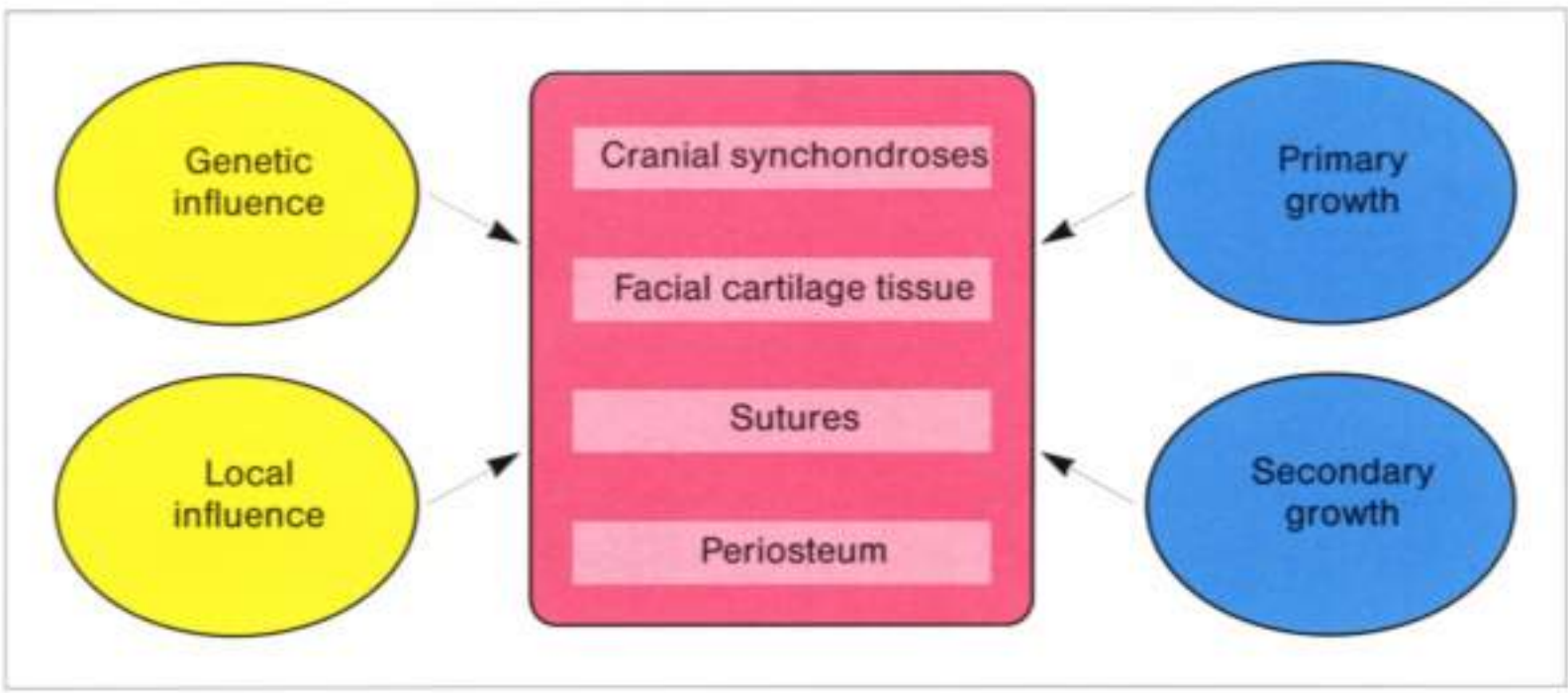


4

Growth-Controlling Factors

Postnatal bone growth, comprising enlargement and remodeling, is based on the intramembranous and endochondral ossification processes which take place in the flat bones, the epiphyses, and sutures. (The long and short bones of the diaphyses of newborn babies are already ossified!) Postnatal growth processes take place within a *time period of approximately 20 years.* They occur within the individual structures to varying amounts at different intervals and are oriented in various directions. The control of such complex morphogenesis requires a precise biologic regulator mechanism. The most important questions from the orthodontic point of view are: To what degree are these developmental processes determined by pure intrinsic genetics, and which factors influence the osteogeneous control system? The various points of view on these key questions are expressed in the divergent concepts of different "orthodontic schools".

The three most common *growth hypotheses* differ, in that the main control function of the morphogenesis is associated with a different tissue type. According to Sicher (1952), osteogenesis of the chondrocranium and desmocranium is controlled purely genetically, and the sutures are the dominant tissue structures. Scott (1967) applies this control mechanism to the cartilage and periosteal tissues, whereas Moss and Salentijn (1969)



50 Control mechanisms governing the growth of the facial skeleton
Compilation of the most important parameters.

localize the control function for craniofacial osteogenesis in the surrounding soft tissues rather than the hard tissues. More recent hypotheses assume that postnatal facial skeletal development is controlled by a multifactorial system which is influenced by intrinsic, genetic, and local factors (van Limborgh, 1970 and Petrovic, 1970).

If one assumes that bone formation is determined by endogenic preprogramming only (Sicher, 1952), orthodontic treatment of hereditary malocclusions would have a poor prognosis throughout the entire growth period.

If osteogenesis can be influenced by local factors, then there are several questions concerning the *therapeutic aspects:*

1) Which local factors are important for craniofacial growth?
2) Which tissues can they influence?
3) To which degree and
4) at which point in time can local factors affect the morphogenesis?

Local Factors Concerning Craniofacial Morphogenesis

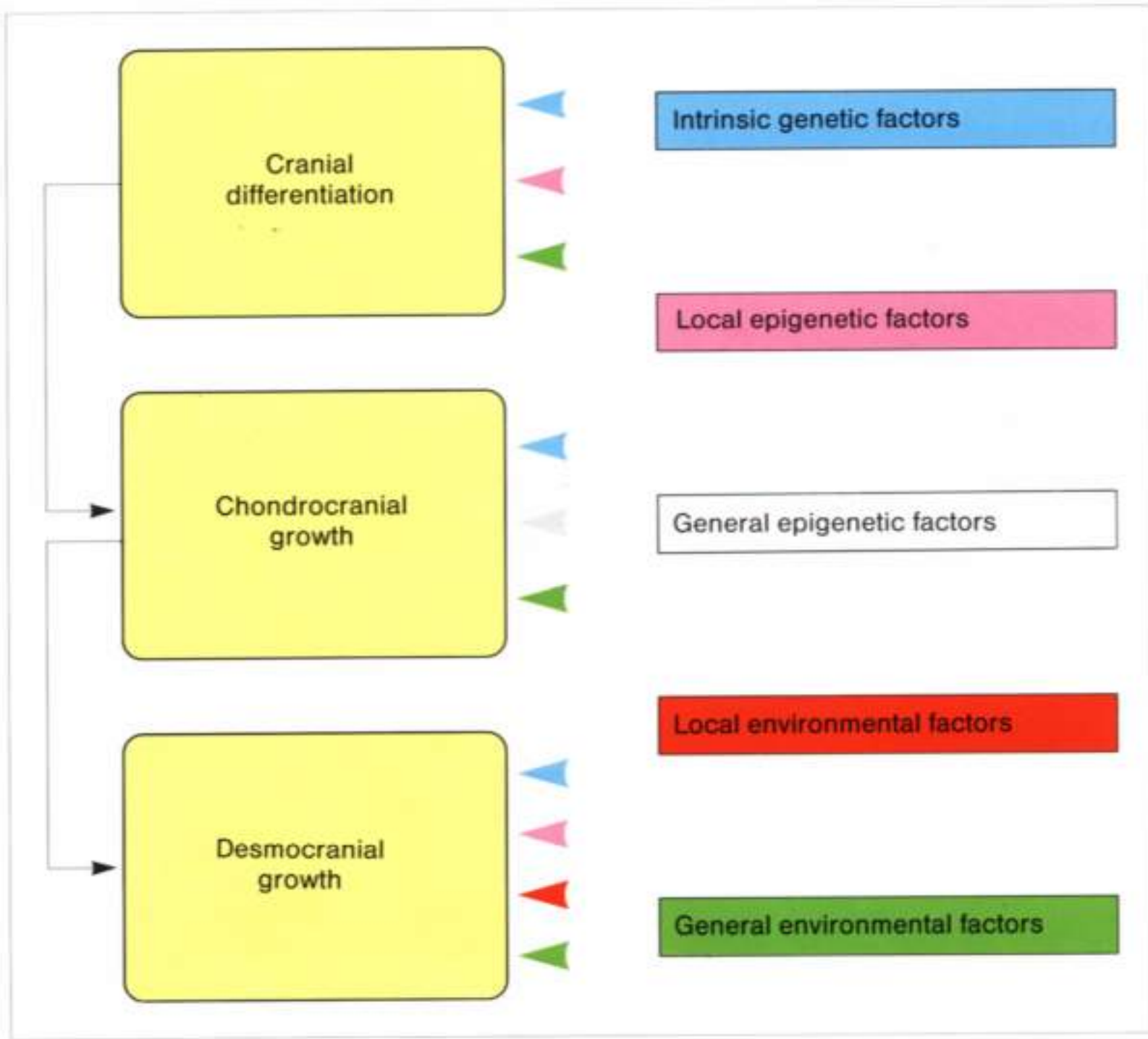
According to van Limborgh (1970, 1972) craniofacial morphogenesis is *controlled by five different factors:*

Intrinsic genetic factors, local and general epigenetic factors, and local and general environmental factors.

According to this growth theory, local factors as well as genetic and general factors can cause anomalies.

The *intrinsic genetic* factors exert their influence within the cells in which they are contained and determine the characteristics of cells and tissues.

Epigenetic factors are those which are determined genetically, and are effective outside of the cells and tissues in which they are produced. Epigenetic factors only occur indirectly, due to reactions of the structures which they influence. According to van Limborgh, these factors can have an effect on the adjacent structures such as local epigenetic factors (e.g. embryonic induction influences, brain, eyes, inner ear) or are produced at distance and exert a general epigenetic influence (e.g. sex and growth hormones).



51 Mechanisms controlling craniofacial morphogenesis (according to *van Limborgh*, 1972)

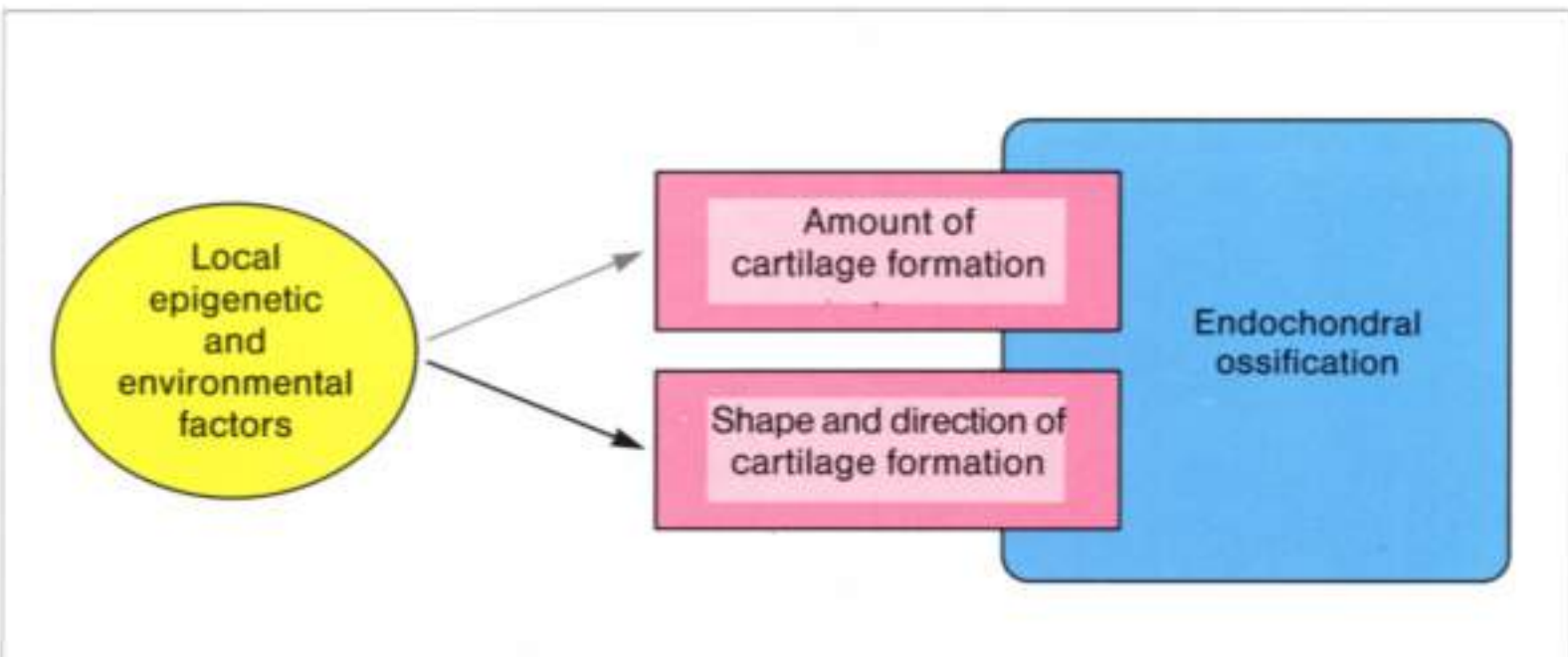
Both, local and general *environmental factors* regulate or modify the morphogenesis controlled by the genome. The *local* environmental factors (e.g. muscular force during functional appliance therapy) are of much greater relevance to the postnatal craniofacial growth control than the general factors (e.g. food, oxygen supply). In order to be able to assess the importance of local factors to the etiology of malocclusions and to possible types of treatment, their effect on the two different forms of craniofacial bone growth, i.e. endochondral ossification and intramembranous ossification, must be taken into account (Fig. 51).

Factors Influencing Endochondral Ossification

Growth of the cranial synchondroses (e.g. sphenoethmoidal and spheno-occipital synchondrosis) and that of the subsequent endochondral ossification are determined by chondrogenesis. Chondrogenesis is primarily influenced by *genetic factors*, similar to growth of the facial mesenchyme during early embryogenesis and to the differentiation phase in cranial cartilage and bone tissue.

The process is minimally affected by local epigenetic and environmental factors. This explains the fact that the cranial base is more resistant to deformation than the desmocranium.

Local epigenetic and environmental factors can neither promote nor impede the amount of cartilage formation. They merely have a slight effect on the shape and direction of endochondral ossification. This effect has been primarily analyzed during growth of the mandibular condyles (Fig. 52).



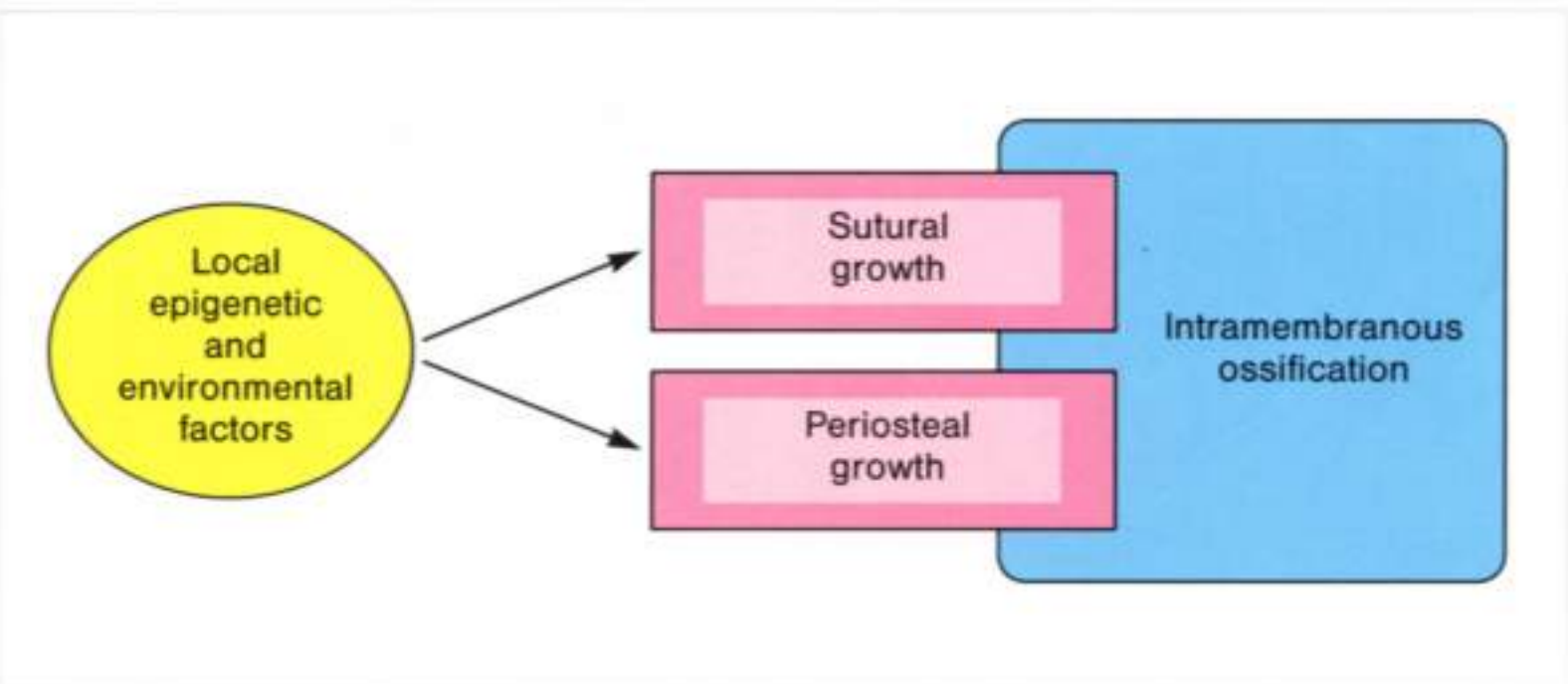
52 Endochondral ossification
Local epigenetic and environmental factors only influence the shape and direction of cartilage formation during endochondral ossification (according to *van Limborgh*). Taking into account the fact that condylar cartilage is a secondary type of cartilage, it is claimed that local factors exert a greater influence on mandibular condylar growth.

Factors Influencing Intramembranous Ossification

Intramembranous ossification of the desmocranium (sutures and periosteum) is mediated by skeletogenetic mesenchymal structures and achieved by bone deposition and bone resorption.

This process is controlled almost entirely by means of *local epigenetic and local environmental* factors (i.e. by muscle force, local external pressure, brain, eyes, tongue, nerves, and indirectly, by endochondral ossification). The genetic factors only have a nonspecific morphogenetic effect on intramembranous ossification and only determine the external boundaries and the amount of growth as well as the growth periods.

Whereas genetically generated anomalies primarily affect endochondral ossification, local epigenetic and local environmental factors, including orthodontic therapeutic measures, affect intramembranous ossification directly (Fig. 53).



53 Intramembranous ossification
Local epigenetic and environmental factors are considered to be parameters influencing intramembranous ossification.

Degree to Which the Growth Processes Can Be Influenced

Osteogenesis is mostly influenced by local functional demands. Moss (1962) described these interrelations in his so-called "functional cranial analysis," which is fundamental to the etiological and therapeutical assessment of malocclusions.

According to Moss, a specific cranial component controls each function. The size, shape, and spatial position of the individual components are relatively independent of one another. Each component of the skull consists of two parts, the *functional matrix* and the *skeletal unit*. The functional matrix includes the functioning spaces and the soft tissue components required for a specific function (e.g. breathing, sight, smell, and mastication). The functional matrix carries out a given function, whereas the skeletal units such as bone, cartilage, and ligaments protect and support the functional matrix and are adaptable.

Functional matrices. There are two types of functional matrices, the periosteal matrix and the capsular matrix.

The periosteal matrix is best exemplified by a muscle attachment. Capsular matrices are divided into three types, i.e. neurocranial, orbital, and orofacial (Fig. 54).

Skeletal unit. The skeletal unit is composed of microskeletal and macroskeletal units. The sum of the microskeletal units of a skull component makes up the macroskeletal unit (Fig. 55).

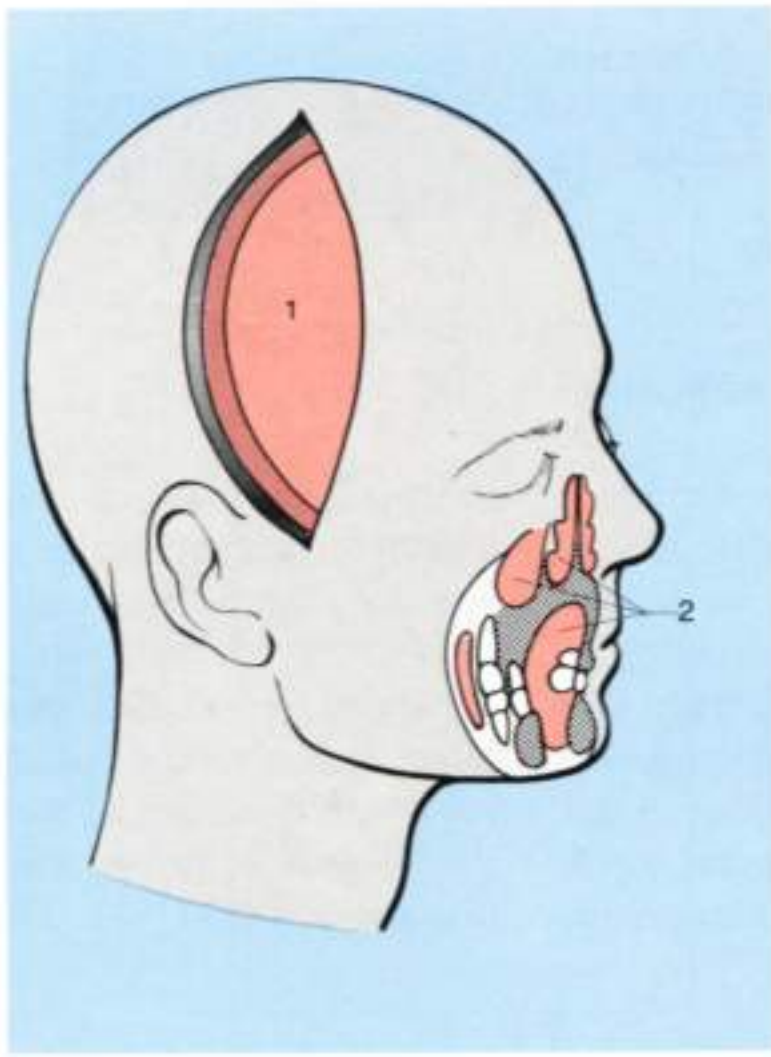
Functional cranial components. The neural mass, the contents of the orbit, and the functional sinuses of the orofacial matrix are protected and supported by a capsule (capsular matrix). The skeletal units are embedded in the capsule together with their specific functional periosteal matrices, i.e. the muscle attachments. They are combined to form the functional cranial components.

54 Capsular matrix

1 = Neurocranial capsular matrix
2 = Orofacial capsular matrix

Diagrammatic view of the neurocranial and orofacial capsular matrices. The neurocranial capsular matrix is represented by the neural mass which is formed by the brain, leptomeninges, and the cerebrospinal fluid.

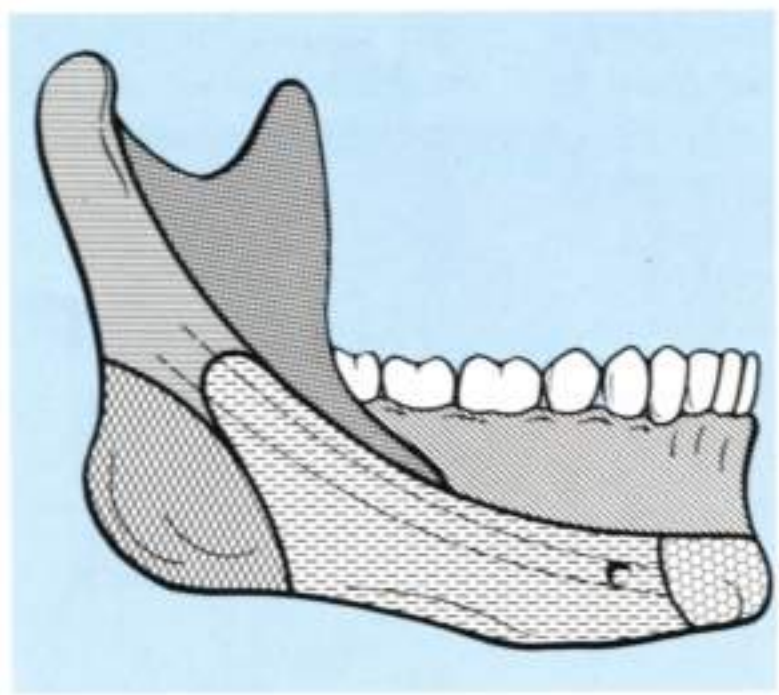
The orofacial capsular matrix is formed by the oral, nasal, and pharyngeal functioning spaces (*Moss* and *Salentijn*, 1969).

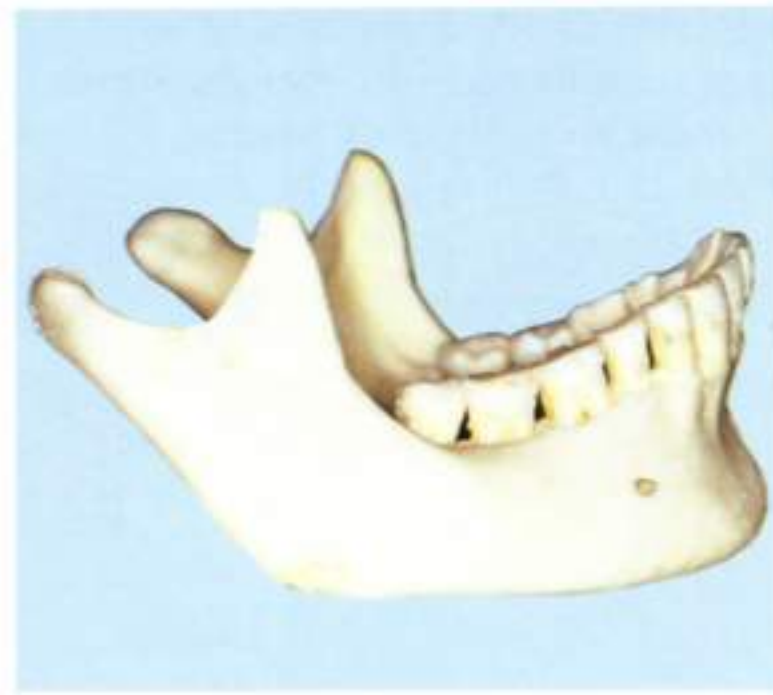


55 Skeletal units of the mandible

The mandible is an example of a macroskeletal unit and consists of the condylar, coronoid, angular, alveolar, and basal microskeletal units.

The temporalis muscle is the periosteal matrix of the coronoid unit and the masseter and medial pterygoid muscles are those of the angular processes. The teeth influence the alveolar unit and the blood vessels and nerves of the mandibular canal have an effect on the basal unit (*Moss*, 1962).





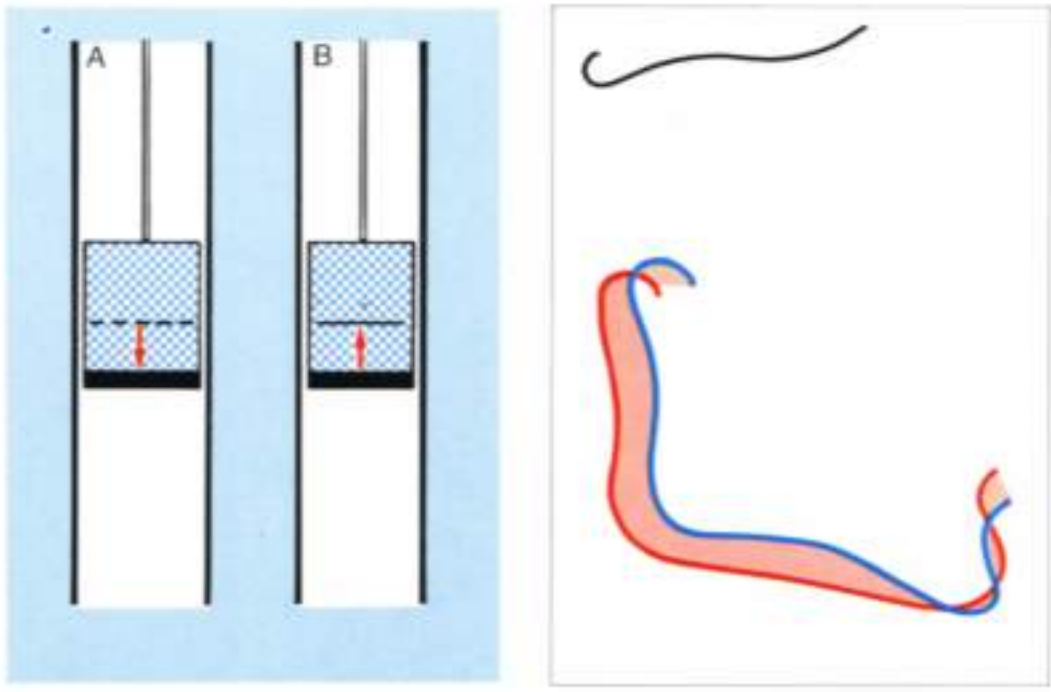
Mechanism of the Functional Matrices

The capsular and periosteal matrices have a completely different effect on the growth processes.

The *capsular matrix* exerts a direct influence on the macroskeletal units and the functional cranial components, and is only responsible for changes in the three-dimensional position of the skeletal unit.

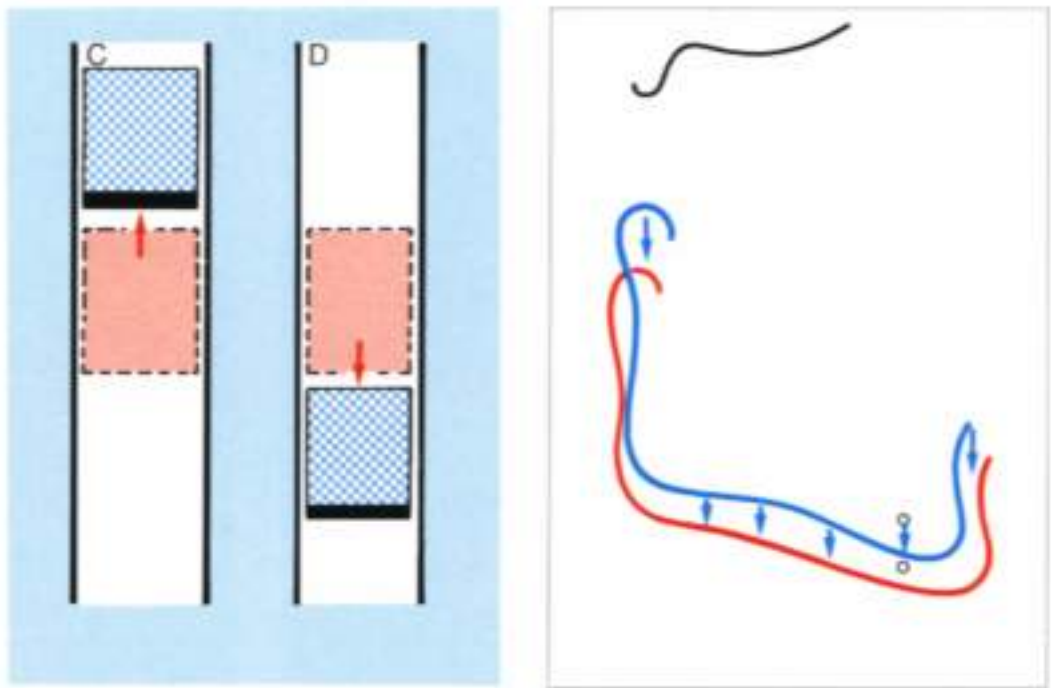
The *capsular matrix* exerts a direct influence on the macroskeletal units and the functional cranial compotion, or perichondral or endochondral growth processes. Thus, the periosteal matrix changes the shape and size of the corresponding microskeletal unit.

Moss (1973) termed this change in size and in shape during growth "transformation" (Fig. 56) and the change in spatial position "translation" (Fig. 57). Only a small percentage of the bone growth in the facial skeleton is due to pure transformation or pure translation. A combination of both types of growth is usually involved (Fig. 58), although translation almost always results in bone transformation (Fig. 62).



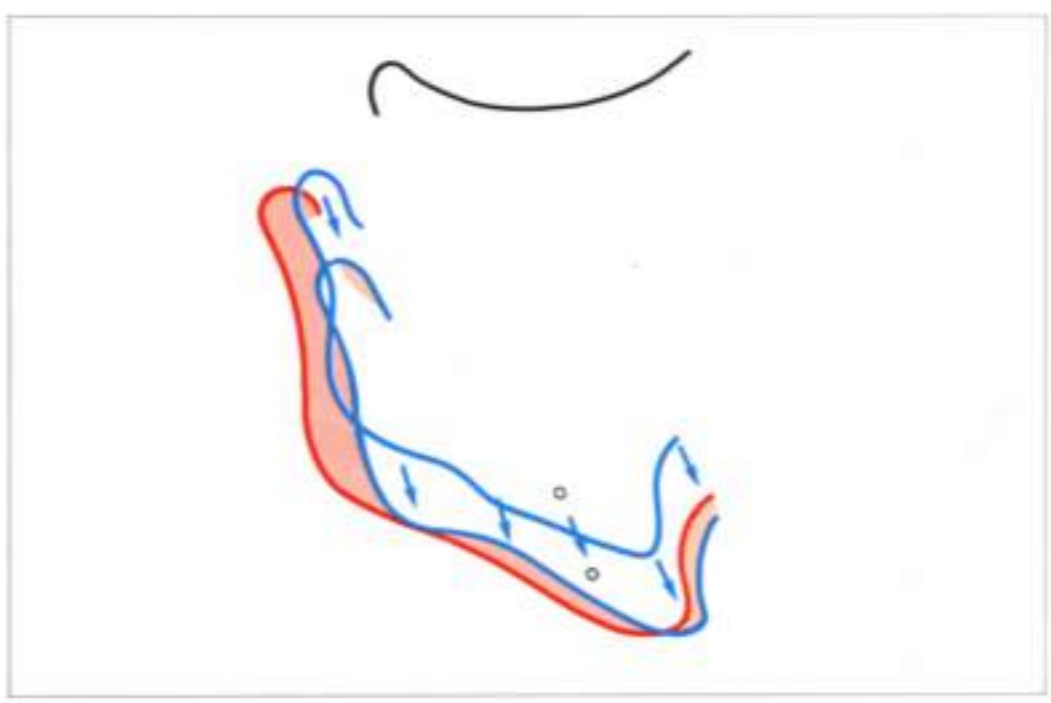
56 Transformation
Left: Schematic view showing the periosteal matrix as an elevator car. The elevator passenger represents the skeletal unit. The passenger can be spatially moved upward or downward by simply transforming the floor of the car (removing [A] or raising the floor boards [B]) (according to *Moss*, 1973).

Right: Illustration showing pure transformation of the mandible, induced by deposition and resorption (deposition = red, resorption = hatched).



57 Translation
Left: Both diagrams show the skeletal macro-unit as an elevator car and the neuromuscular capsule as the elevator shaft. Upward movement (C) and downward movement (D) reposition the car (translation) (Moss, 1973).

Right: Schematic view showing pure downward translation of the mandible.



58 Transformation and translation of the mandible

Red = Bone deposition
Hatched = Bone resorption

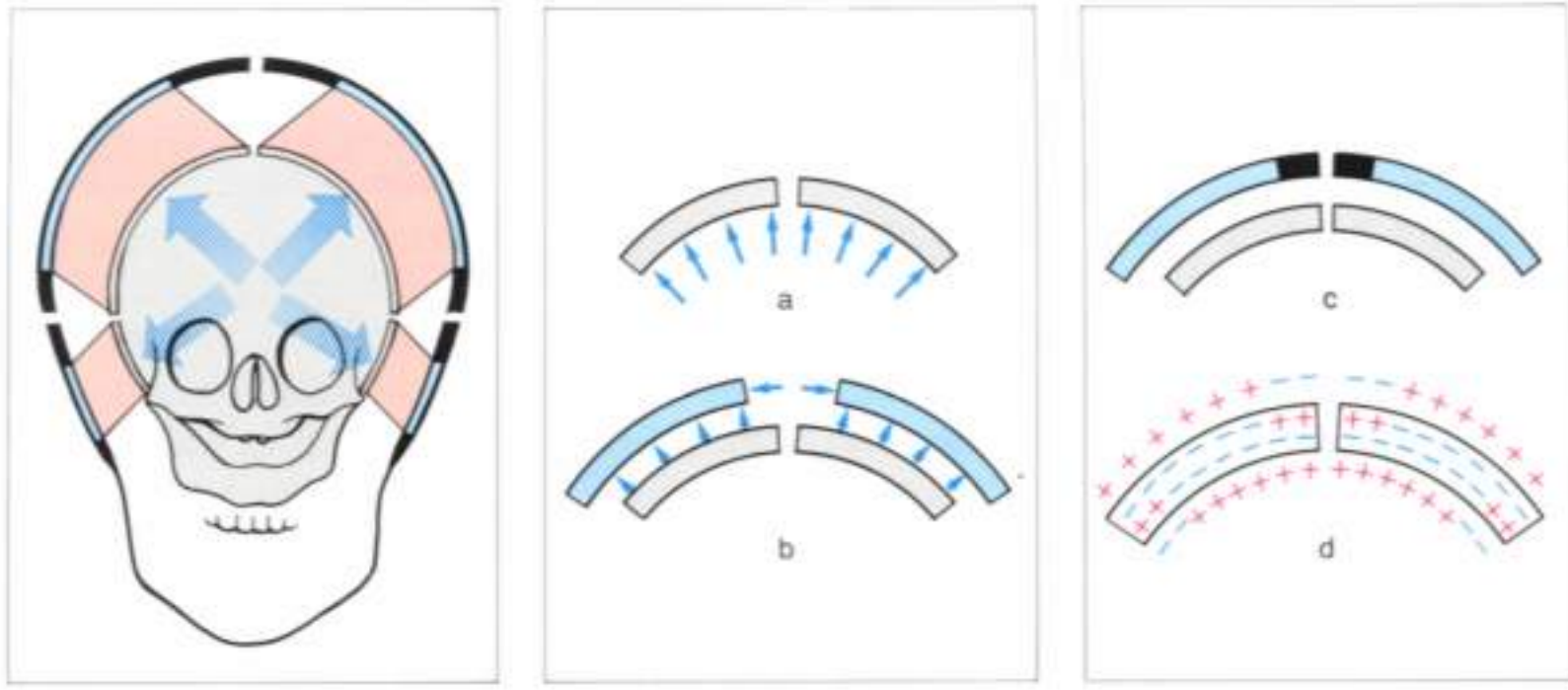
Downward and upward growth of the mandible is primarily due to a translation process which corresponds to the expansion of the orofacial functioning spaces (blue contours).

The transformation processes cause the changes around the condyles and gonial angles of the mandible and are of little relevance to the growth of the mandibular body.

59 Mechanism of the neurocranial matrix

Expansion of the neural mass (neurocranial functional matrix) causes passive translation of the flat cranial bones toward the direction of expansion.

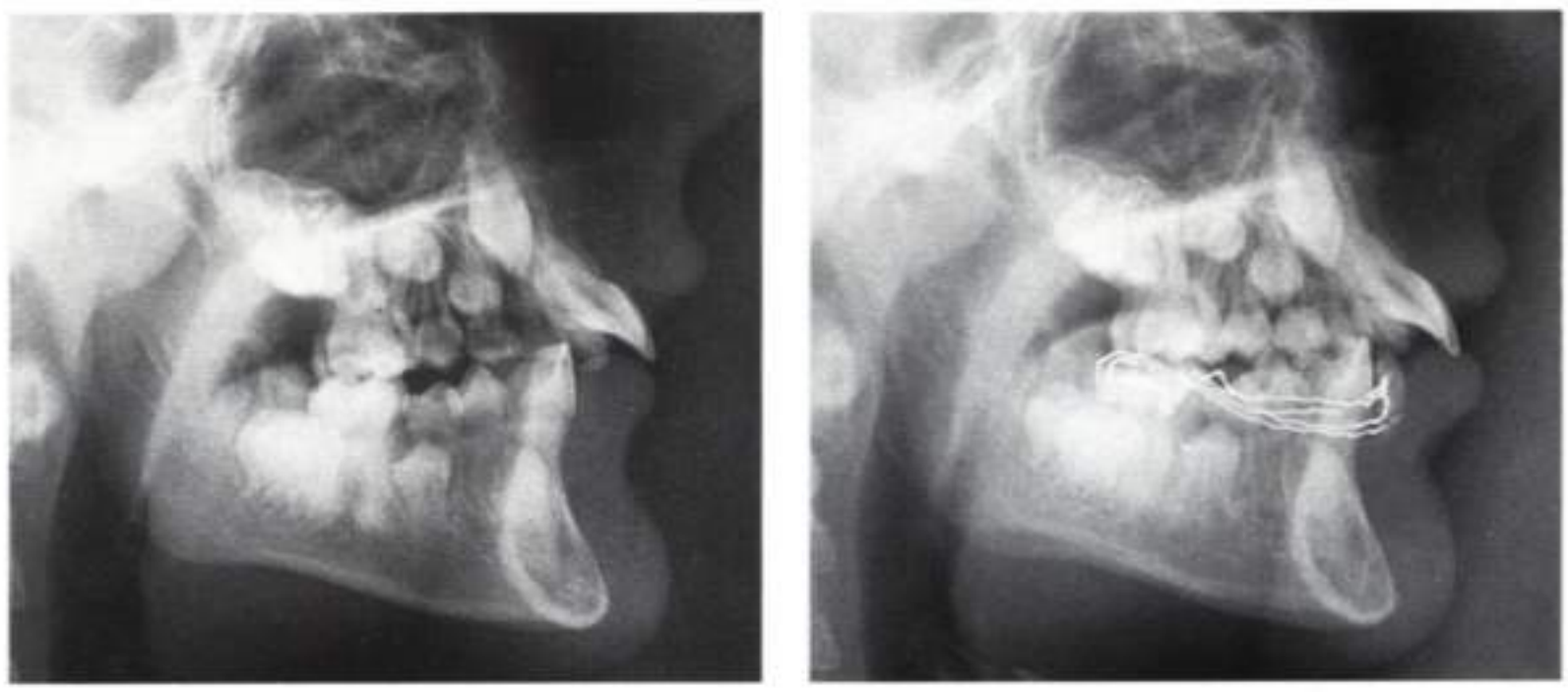
Right: In order to compensate for separation of the calvarial bones (a, b) transformative growth is usually induced along the sutural edges (c). The skull bones are transformed (d) due to the effect of their related functional periosteal matrices (*Enlow*, 1982).



60 Expansion of the orofacial capsular matrix

The case shown on these two lateral cephalograms indicates that use of a lower lip screen increases the volume of the oral cavity.

A secondary effect is that the functional loading on the individual periosteal matrices is changed and the skeletal units embedded in the capsule are translated and transformed accordingly.



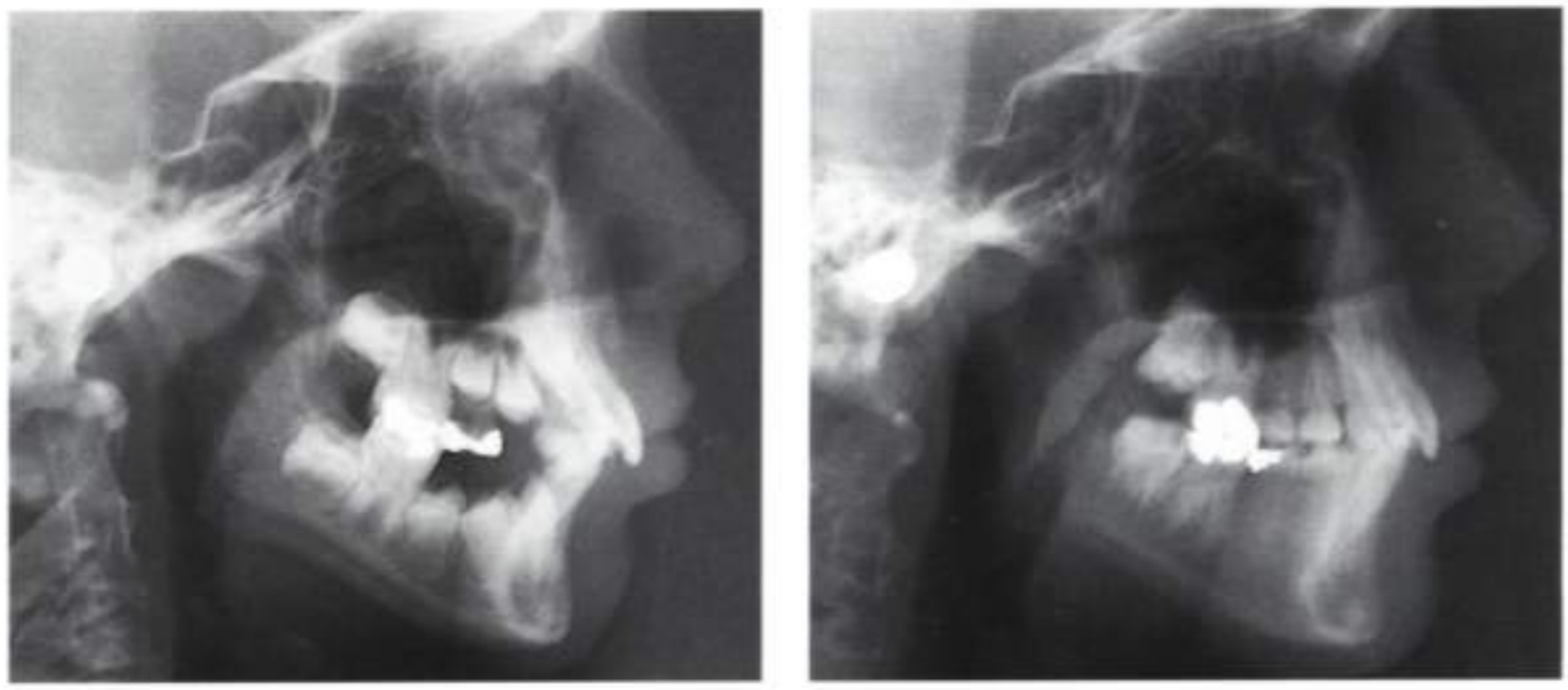
Transformation and translation of the mandible using an activator

61 Class II malocclusion

Radiographic cephalogram of a 9-year-old patient at the beginning of orthodontic treatment.

Right: Cephalogram of the same patient after 3 years of activator therapy. The mandible was translated inferiorly during the course of treatment, and simultaneously the length of the mandibular corpus increased by 7 mm.

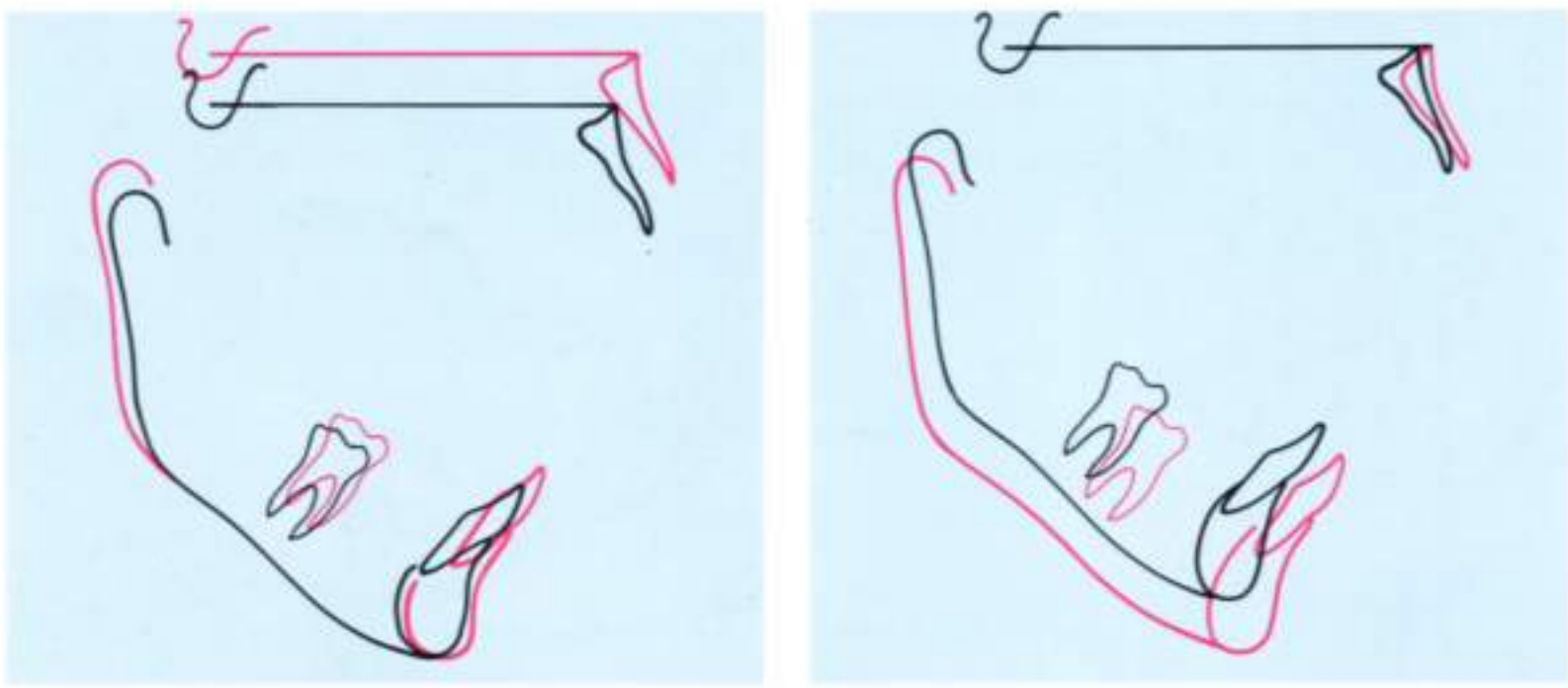
The cephalometric tracings are superimposed in Fig. 62.



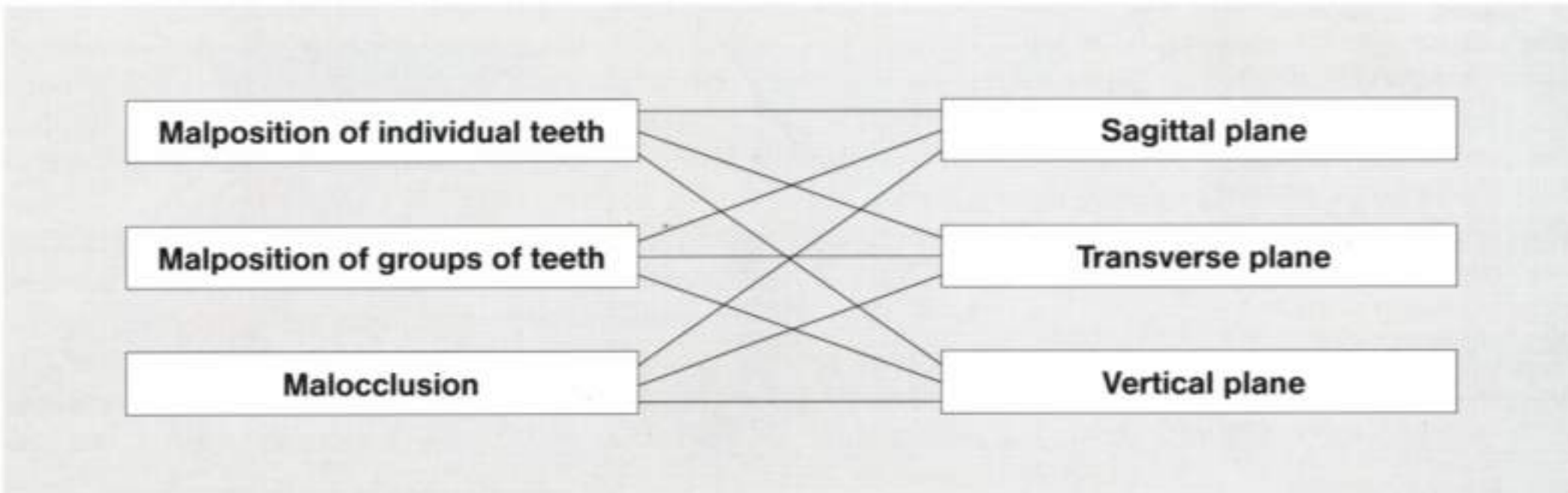
62 Assessment of the changes in position and shape of the mandible

Superimposition of the two tracings in the area of maximum congruency of the bodies of the mandibles to illustrate mandibular remodeling.

Right: Total mandibular displacement is the change in position of the mandible along the line S–N (black = prior to, red = after treatment). The translation is the difference between total displacement and local transformation (according to *Baumrind* et al., 1983).



Classification of Malposition – Nomenclature



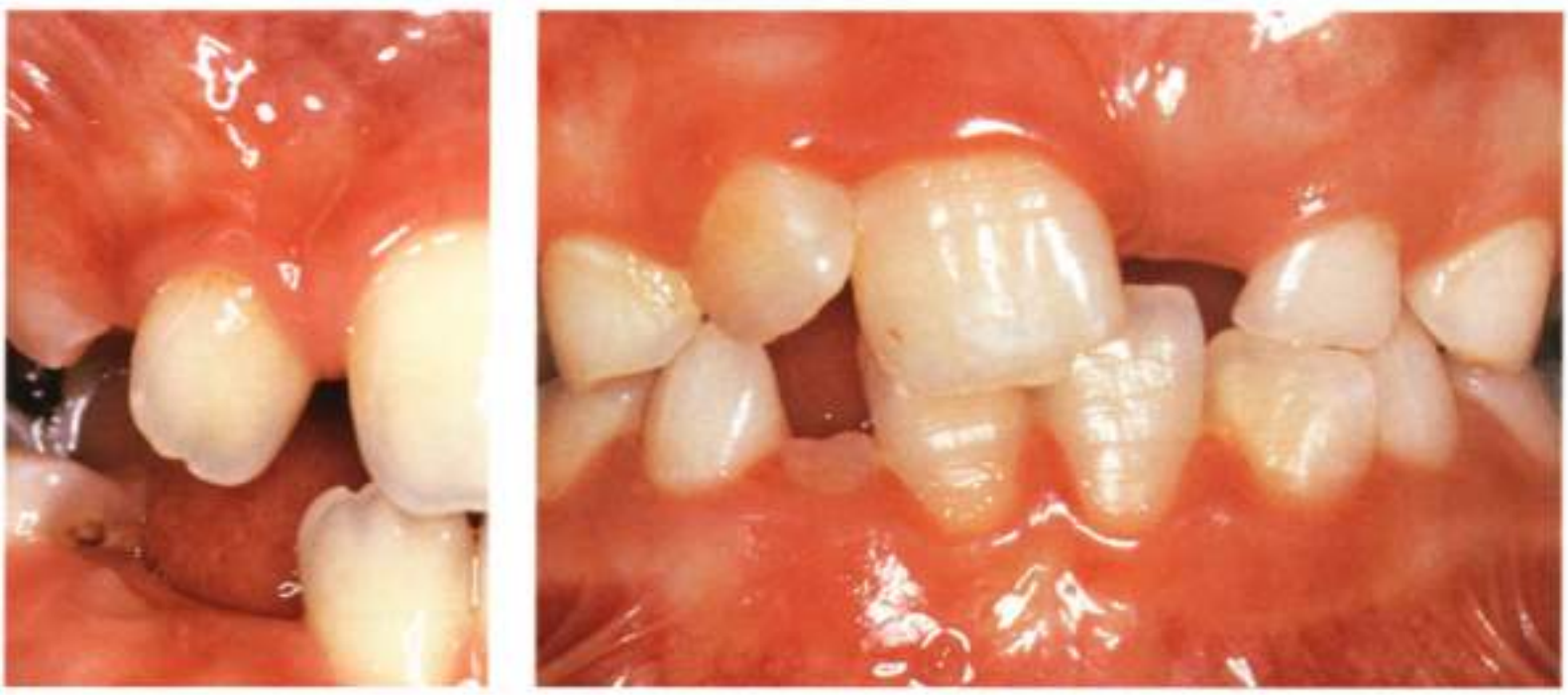
Malposition of Individual Teeth

Malpositions of individual teeth may be classified as follows:

- Rotation
- Inclination
- Centric or eccentric malposition
- Total displacement
- Retention
- Transposition

Lischer's nomenclature describes malpositions as:
1) Mesio- and distoversion
2) Linguo-/labioversion and buccoversion
3) Infra- and supraversion
4) Axi- and torsiversion
5) Transversion

Localization of the axis of rotation is an important criterion for treating abnormally inclined or rotated teeth. Centric and eccentric rotation are differentiated according to the position of the longitudinal axis of rotation.

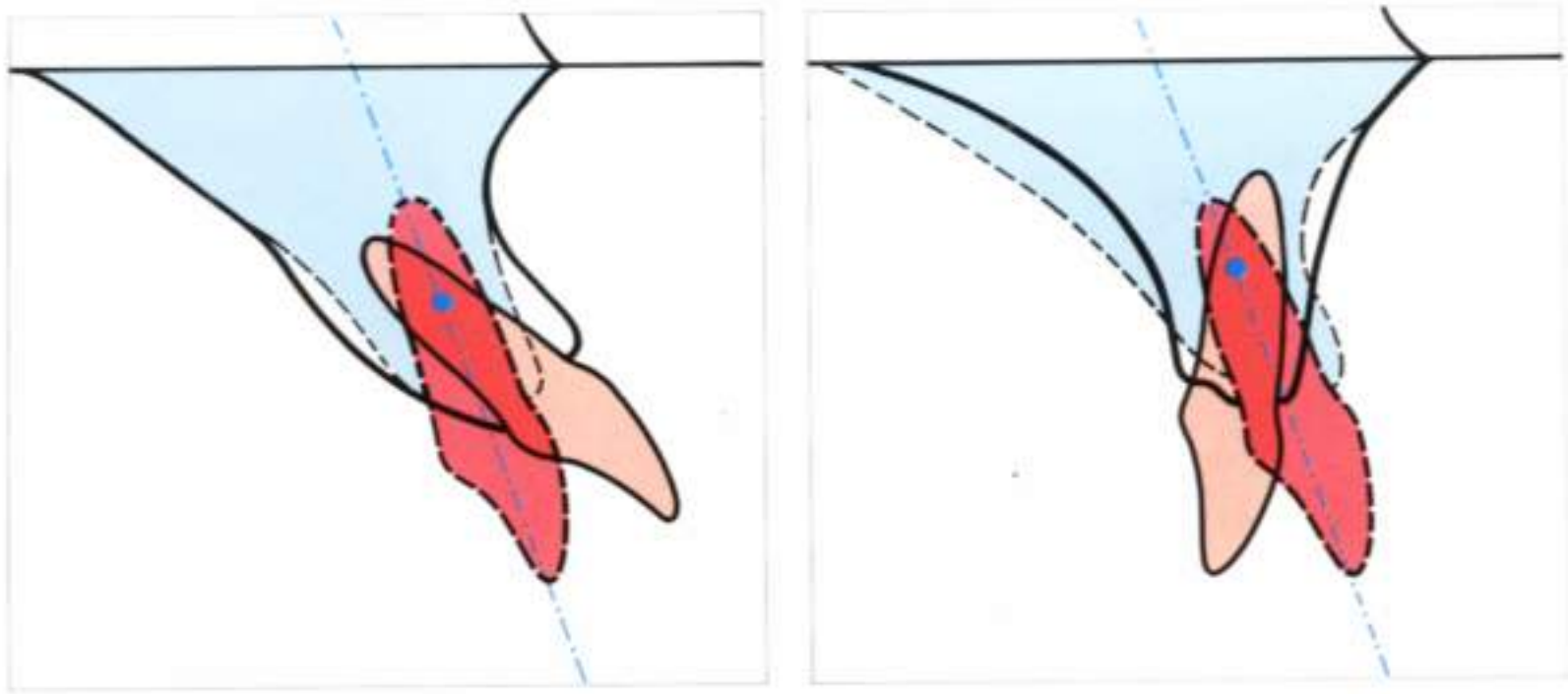


63 Malposition of individual teeth
Mesial inclination of upper right central incisor with inadequate space for the unerupted tooth on the opposite side.

Left: Distolabial rotation of upper right lateral incisor, combined with distal inclination.

64 Centric tipping of upper teeth
Labial (left) and lingual (right) inclination of an upper incisor.

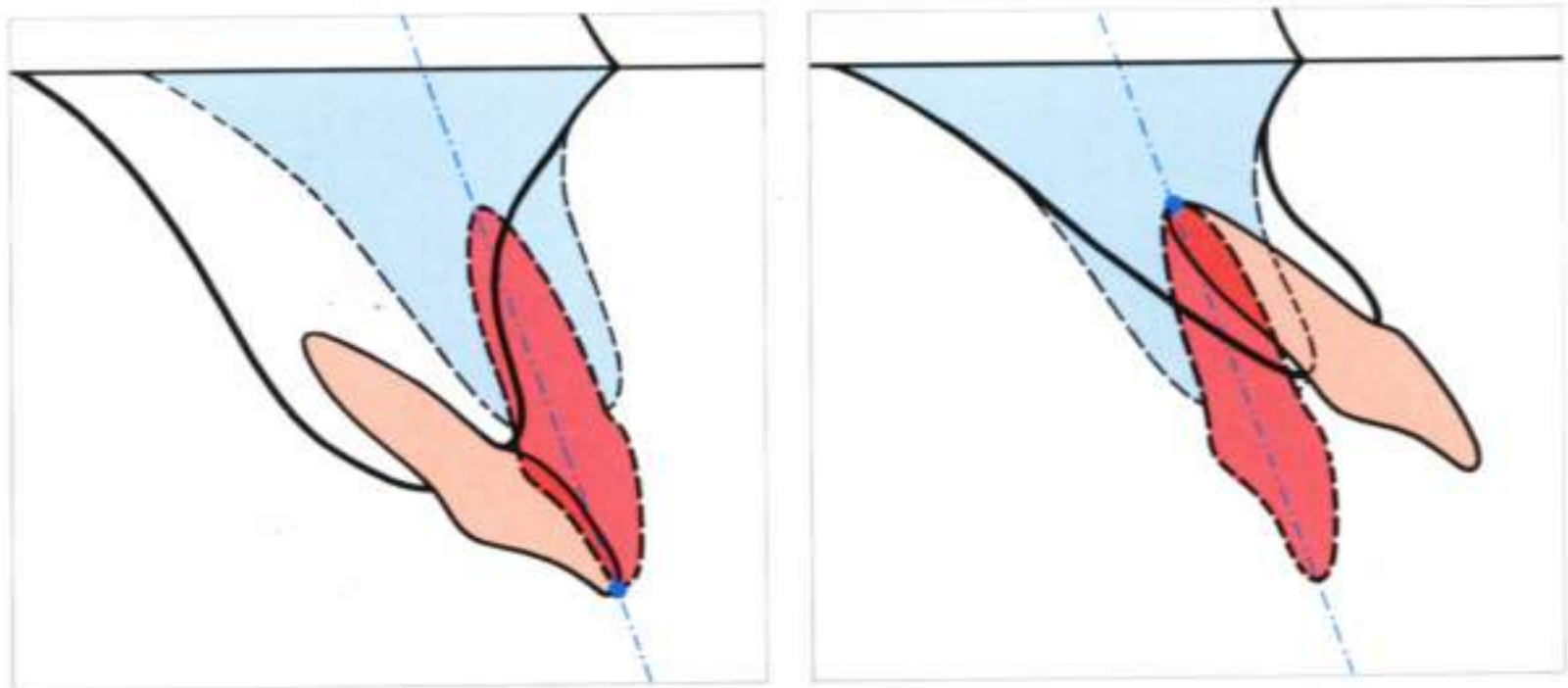
The center of rotation is located between the middle and apical third of the root (*Schwarz*, 1961).



65 Eccentric tipping of an upper incisor
Left: Labial inclination with the center of rotation located in close proximity to the incisal edge.

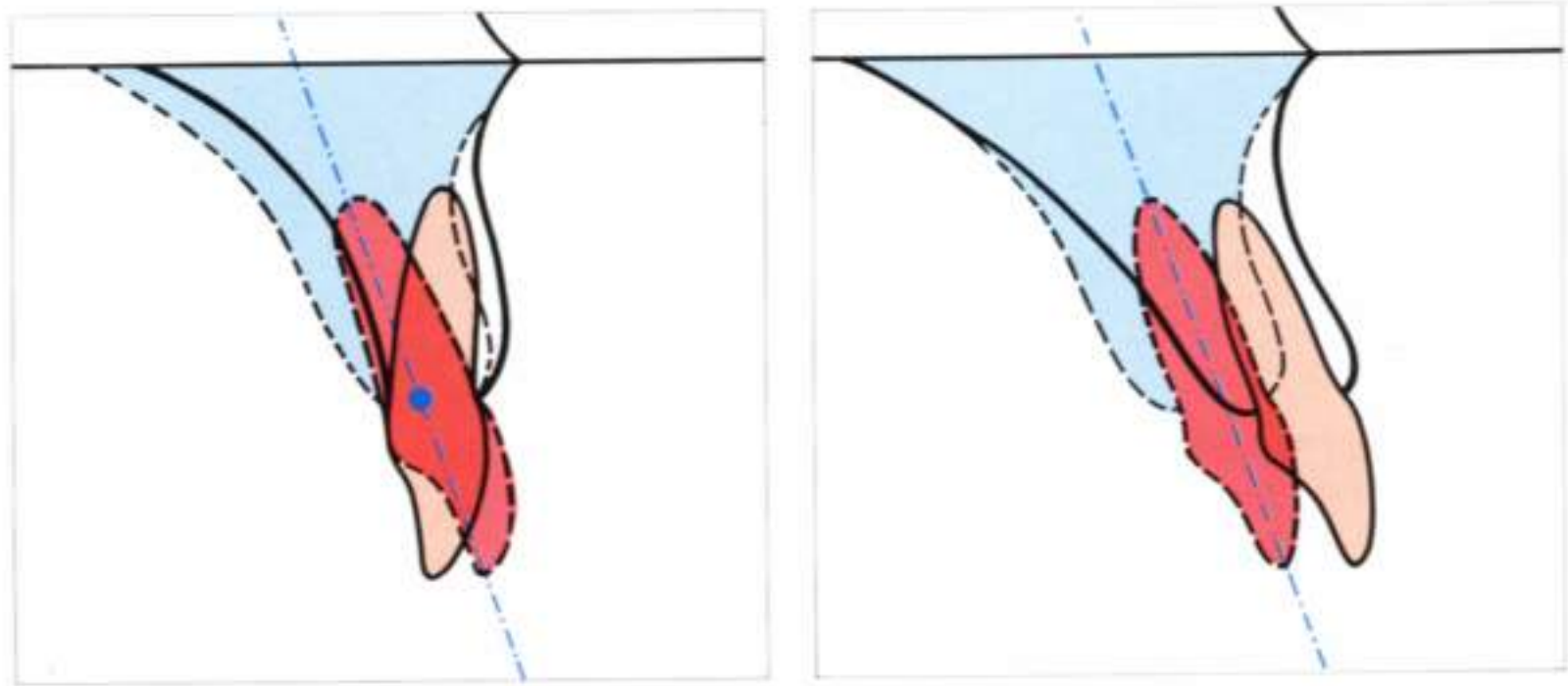
Right: As above, with the center of rotation located in close proximity to the apex of the root.

Should the center of rotation be localized at the apex, the malposition can be aligned by pure tipping in the opposite direction. The further toward the incisal edge the center of rotation is localized, the more complicated is its correction.



66 Tooth tipping – Total displacement
Left: Eccentric lingual inclination, with the center of rotation in close proximity to the neck of the tooth.

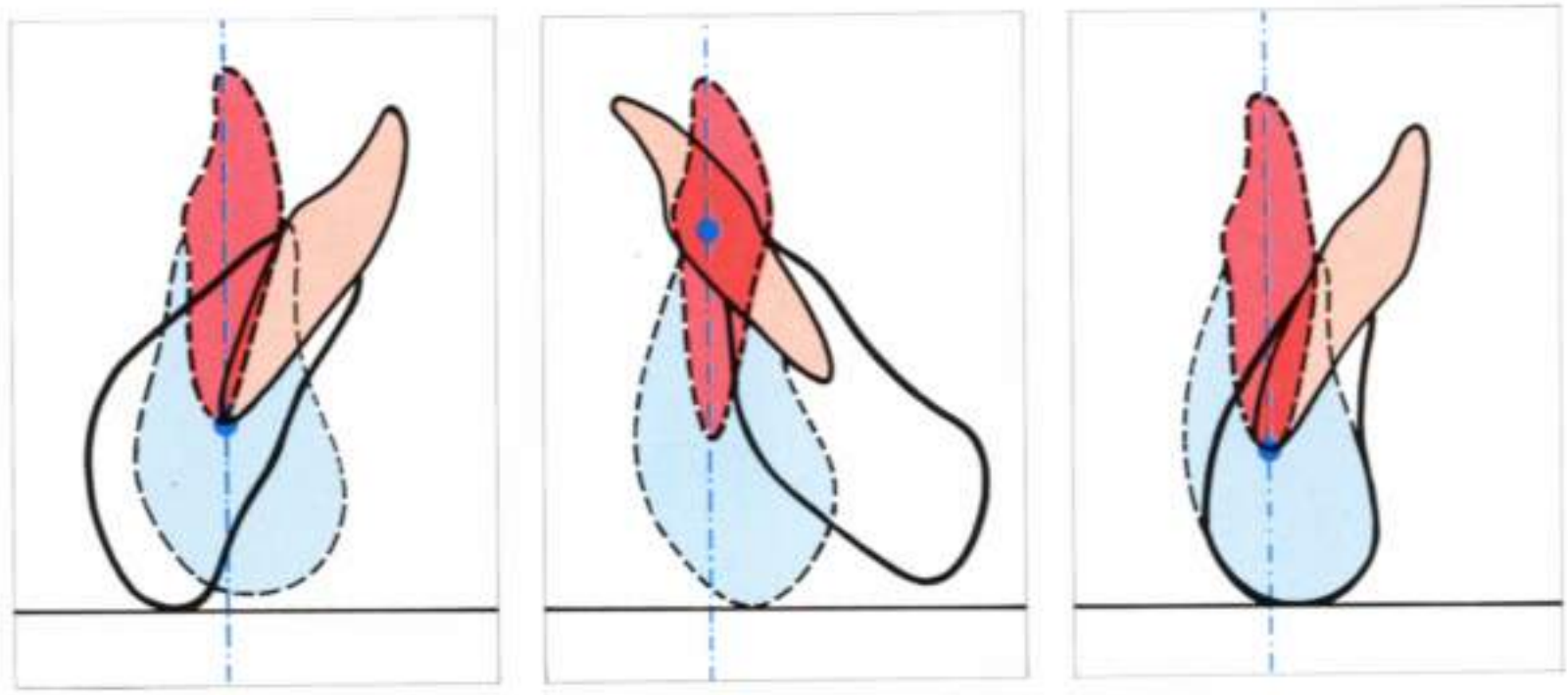
Right: Total displacement. This type of malposition can only be corrected by a bodily tooth movement.



67 Lower tooth inclination
Left: Labial inclination of a lower incisor, with apical base involvement.

Center: Lingual inclination, with apical base involvement.

Right: Labial inclination, without apical base involvement.



Malpositions of Groups of Teeth

Sagittal:	Labioversion, linguoversion, Mesioversion, distoversion
Transverse:	Crowding, linguoversion, spacing, buccoversion
Vertical:	Supraversion infraversion

There are two types of *labioversion:* Labial inclination of anterior teeth with and without spacing.

Linguoversion of the anterior teeth is mostly encountered with a deep overbite and a Class II, Division 2 malocclusion. The latter is subdivided in different types depending on the malalignment of the upper anterior teeth.

Considering the amount of space deficiency, *crowding* is divided into three categories: *first-degree crowding, second-degree crowding, and third-degree crowding.*

The following classifications for crowding take the etiology of the anomaly into account: *primary, secondary,* and *tertiary.* Primary (= herditary) crowding is determined genetically and is caused by disproportionately sized teeth and jaws. The malalignment of the anterior teeth is characteristic of this type of crowding ("Persistence of tooth germ position"). Secondary crowding is an acquired anomaly caused by mesial drift of the posterior teeth after premature loss of deciduous teeth in the lateral segments. The etiopathogenesis of tertiary crowding is still debated. This type of crowding – primarily of the lower anterior teeth – occurs between the ages of 18 and 20 and was previously associated with the eruption of the third molars. Others accredit the anomaly to differential anteroposterior growth of the upper and lower arches terminating at different times.

The terms *"coronal crowding"* and *"apical crowding"* take the inclination of the teeth to their apical bases into account. Narrow maxillary arches are divided into three categories: *anterior constriction, posterior constriction,* and *constriction of the entire arch (constricted arch with labioversion).*

Compared to anomalies with crowding, malalignments of groups of teeth due to interdental spacing and wide arches are uncommon in our population.

Sagittal malalignment of groups of teeth

68 Labioversion of anterior teeth with spacing
Class II malocclusion: The upper incisors are flared labially and spaced.

69 Labioversion of anterior teeth without spacing
Class II malocclusion with labially inclined upper incisors and firm interproximal contacts. Despite the increase in upper arch length due to the labial tipping of the anterior teeth, the upper incisors are not spaced.

Relationships of upper anterior teeth in Class II, Division 2 malocclusions

70 Isolated linguoversion of upper central incisors
The upper centrals are lingually inclined and the lateral incisors are in labioversion.

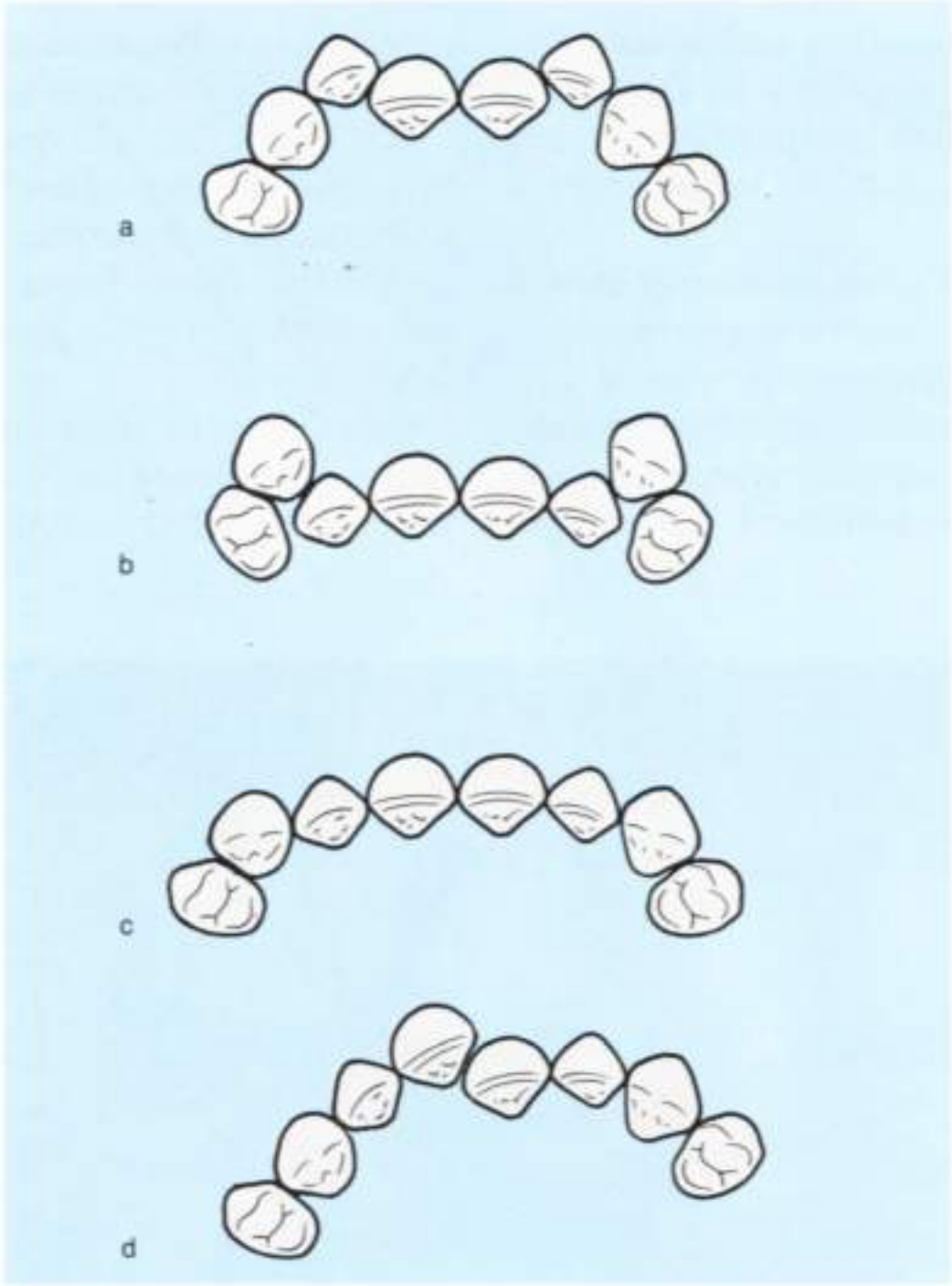
71 Characteristic malalignments of upper anterior teeth in Class II, Divison 2 malocclusion
From top to bottom:

a The central incisors are tipped lingually, the laterals are in labioversion or normally inclined.

b All four incisors are tipped lingually and the canines are in mesiolabioversion.

c Linguoversion of all six anterior teeth.

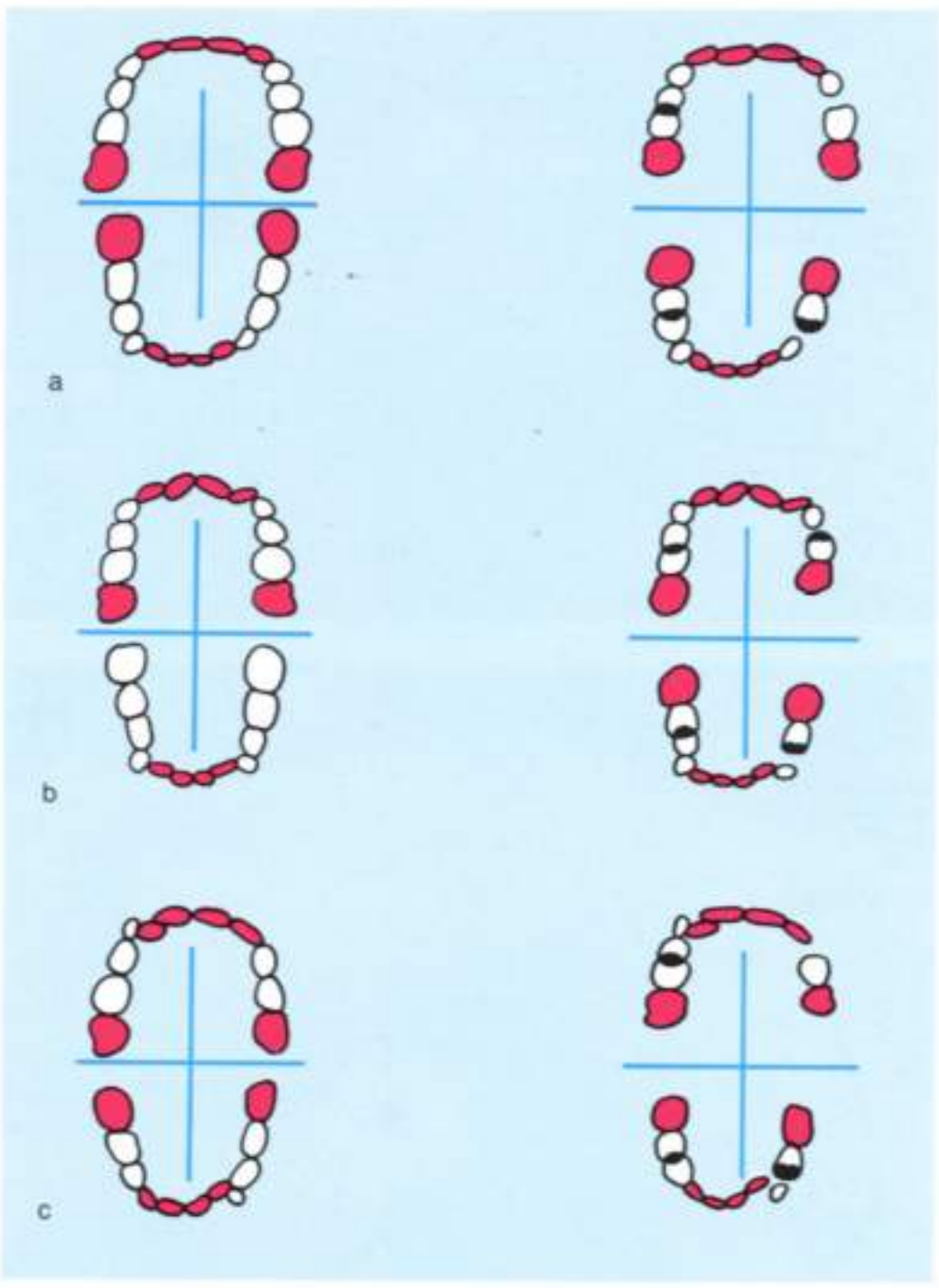
d Mixed type of frontal malposition, with lingually inclined incisors on one side.



72 Unilateral linguoversion of upper incisors
Distoclusion, with a typical Class II, Division 2 malaligment on one side. The incisors on the opposite side are flared labially.

Crowding

73 Second-degree crowding
Malposition of the upper anterior teeth in a mixed dentition. The lack of space around the incisors is clearly visible.



74 Classification of amount of crowding in a mixed dentition

a First-degree crowding: Slight malalignment of the anterior teeth. No abnormality of the supporting zone (= area of deciduous canine, deciduous first and second molar). *Right:* First-degree crowding with restricted supporting zones, as a result of caries and premature loss of deciduous teeth.

b Second-degree crowding: Pronounced malalignment of anterior teeth. No abnormality of the supporting zone.
Right: Second-degree crowding with restricted supporting zones.

c Third-degree crowding: Severe malalignment of all four incisors. The adjacent permanent teeth undermine the deciduous teeth due to unusual root resorption (lack of space greater than the width of the lateral incisor).
Right: Third-degree crowding with restricted supporting zones due to caries and/or undermining resorption (*Hotz*, 1980).

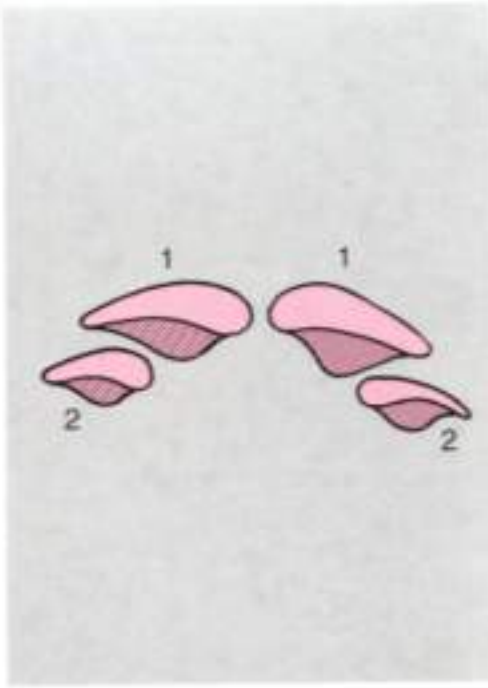
Crowding in conjunction with reduced supporting zones is considered more difficult to treat.

75 Third-degree crowding
Malalignment of the upper arch with extreme lack of space for the anterior and posterior teeth.

Primary crowding – Typical relationships of the upper incisors

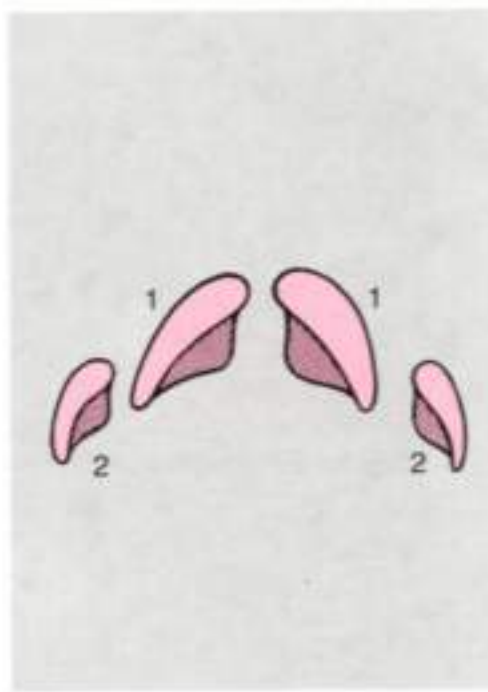
76 "Staggered" position of upper anterior teeth
The "persistent tooth germ position" is a characteristic of hereditary crowding. Lingually blocked out lateral incisors are the most common type of malalignment.

Right: Diagram showing the malposition.



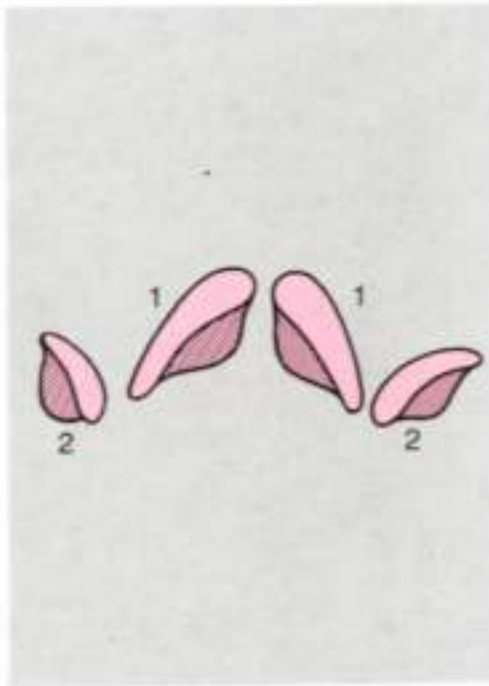
77 Mesiolabial rotation of the incisors
The upper anterior teeth are positioned like roof tiles and exhibit mesiolabial rotation.

Right: Diagram showing the malposition.



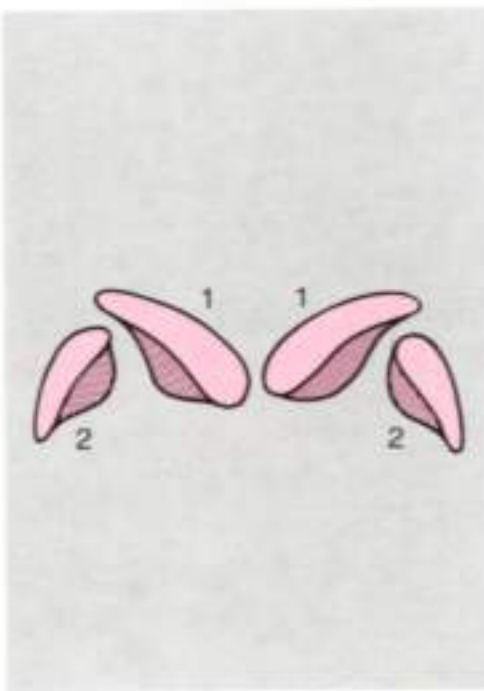
78 Mesiolabial rotation of the upper centrals and distolabial rotation of the upper laterals
"Plough-share" positioning of the upper incisors.

Right: Diagram showing the malposition.



79 Distolabial rotation of the central incisors
Upper centrals positioned like double doors – a characteristic symptom of true tooth-size jaw-size discrepancy.

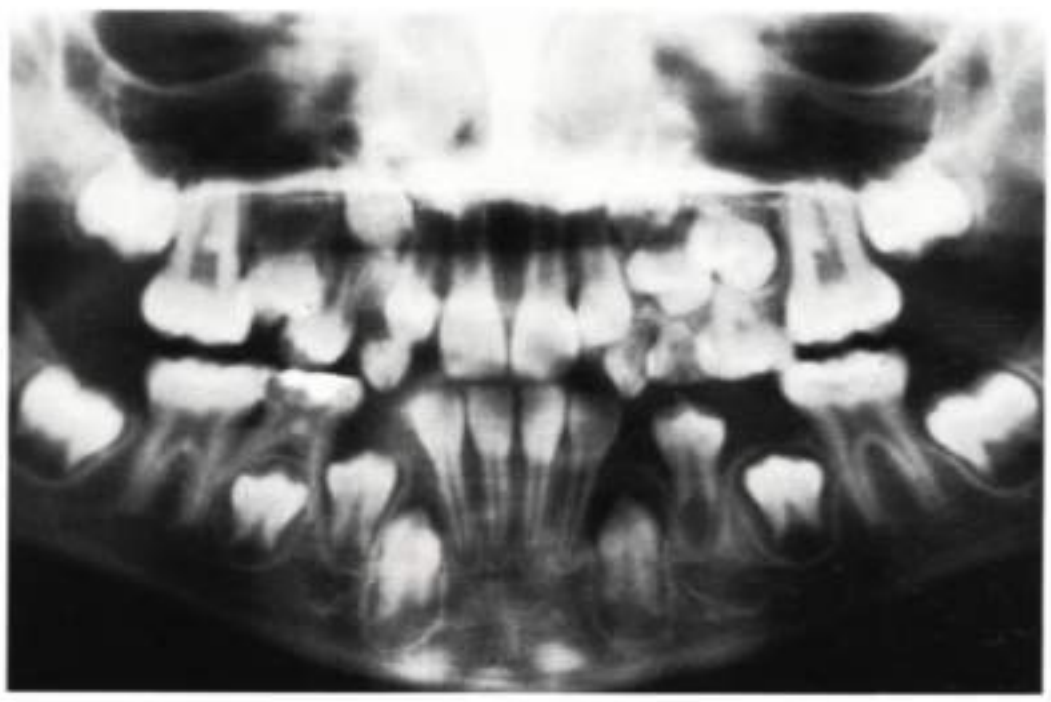
Right: Diagram showing the malposition.



Primary crowding – Clinical symptoms

80 Deciduous dentition

The following symptoms are characteristic in an early mixed dentition: The upper anterior deciduous teeth are without interdental spacing and the lower deciduous lateral incisors are exfoliated prematurely caused by the eruption of the lower permanent central incisors ("undermining or atypical resorption").



81 Undermining resorption in the anterior region

Primary crowding in a mixed dentition, with atypical resorption of the upper deciduous canines due to eruption of the adjacent permanent lateral incisors (undermining resorption).

The same process was also responsible for the premature loss of the lower deciduous canines.

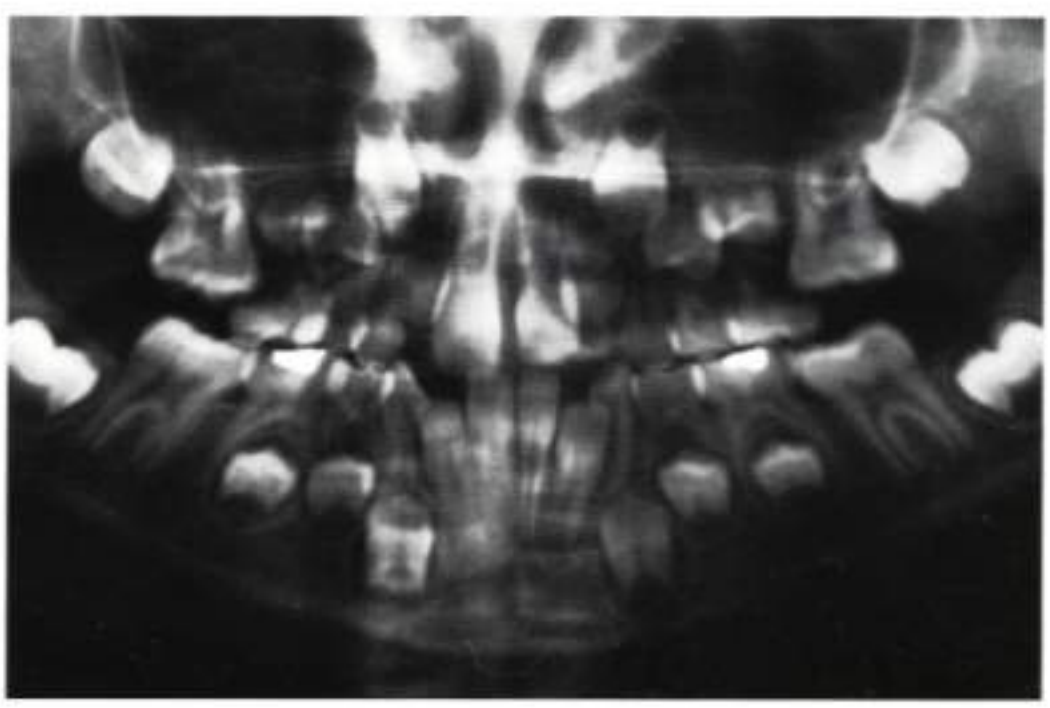
The atypical resorption of deciduous teeth results in restriction of the supporting zones from the anterior.

Undermining resorption of second deciduous molars

82 Clinical findings

Undermining resorption of the upper second deciduous molars by the 6-year molars. This results from a relative underdevelopment of the maxillary tuberosity and a mesially directed eruption of the first permanent molars. This disturbance has partly impeded the eruption of both first molars.

When the first permanent molars emerge and the deciduous molars are lost prematurely, the posterior area of the supporting zones becomes severely restricted.



83 Radiographic findings

Apart from the undermining resorption of the deciduous second molars, caused by the upper first permanent molars, the deciduous canines of all quadrants undergo undermining resorption, caused by the permanent lateral incisors. There is a risk that the upper supporting zones will become restricted from the anterior and posterior sides during the first stage of exfoliation.

Left: Detailed view of undermining resorption of an upper deciduous molar due to ectopic eruption of the 6-year molar.

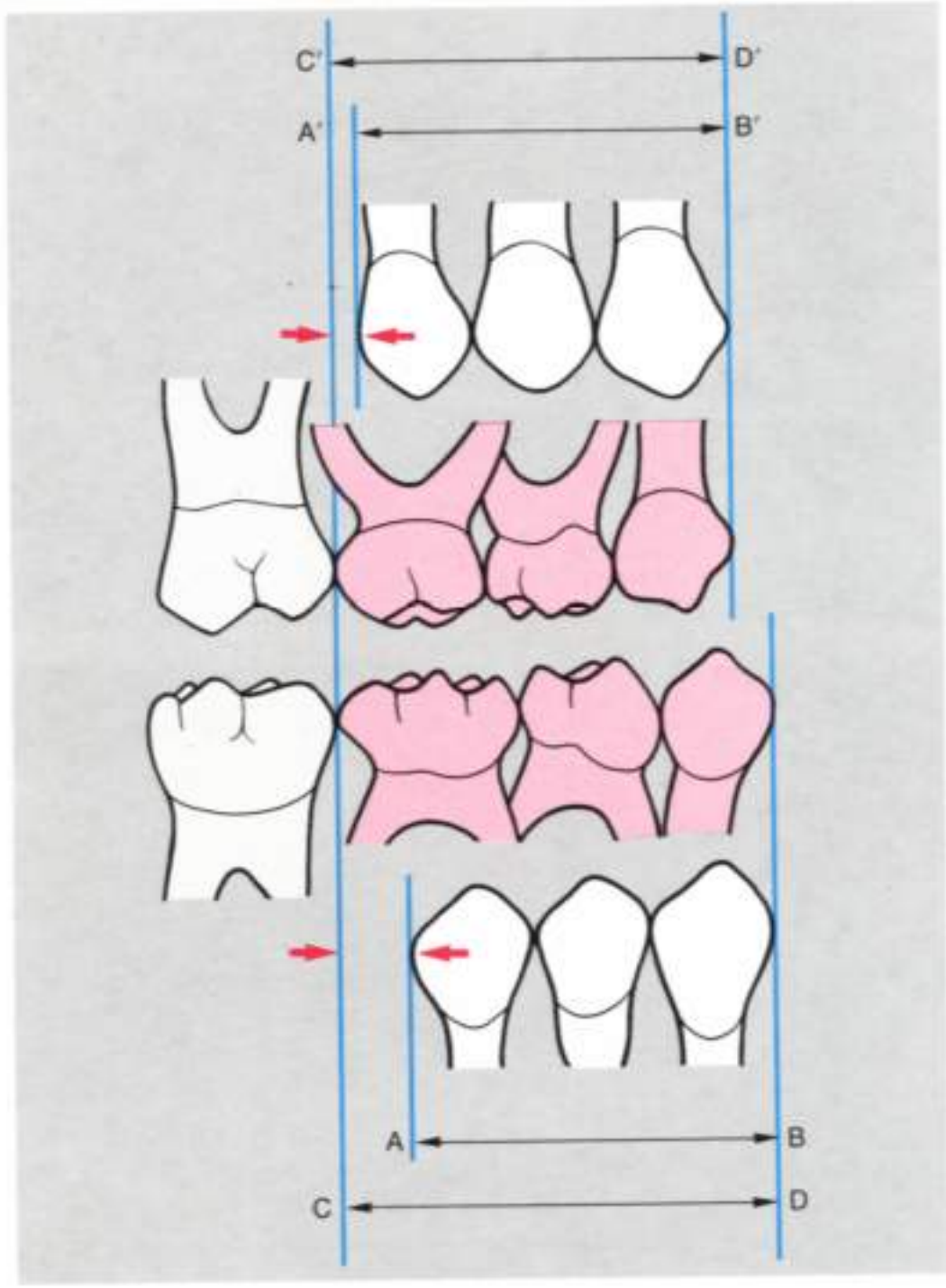
84 Secondary crowding
The lower left supporting zone is reduced due to mesial inclination of the 6-year molar after premature extraction of the second deciduous molar.

85 Supporting zones of the mixed dentition
This section of the dental arch is defined metrically as being the sum of the mesiodistal widths of the deciduous canine, the first deciduous molar and the second deciduous molar.

Maintaining the supporting zone ensures that sufficient space is available for the permanent teeth of this section which have not yet erupted.

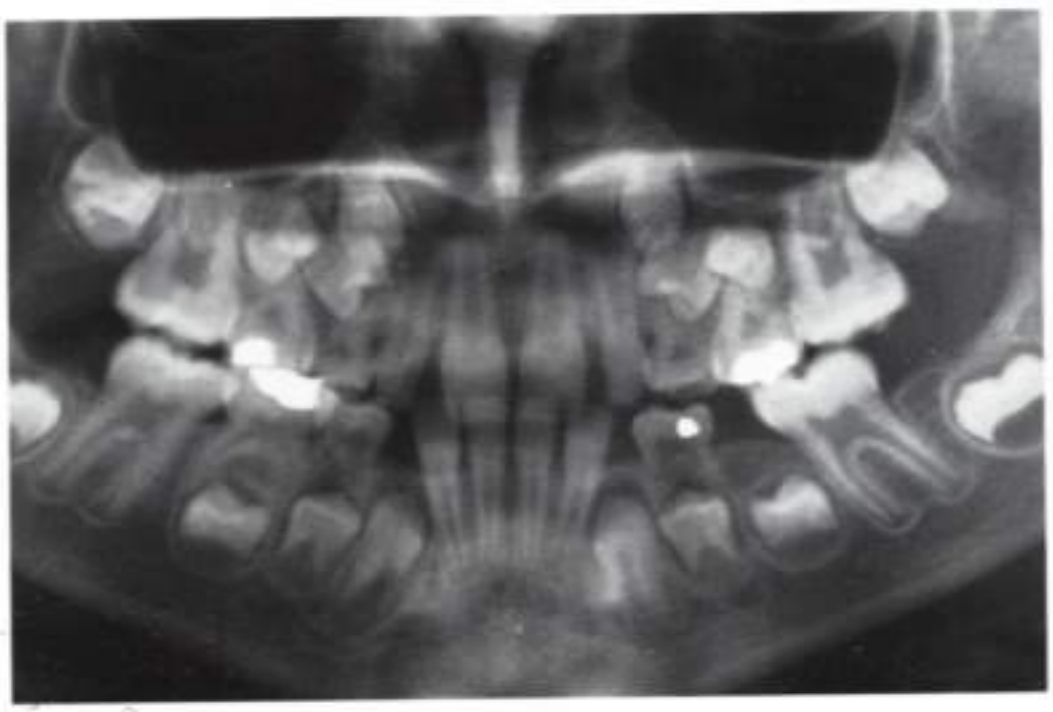
On average, the upper supporting zone (C'–D') is 0.9 mm longer than the sum of the mesiodistal widths of their successional permanent teeth (A'–B'); the lower zone (C–D) is 1.7 mm longer than its respective permanent teeth (A–B). The arrows indicate the difference in width between the supporting zone and the permanent teeth (*Nance's* leeway space).

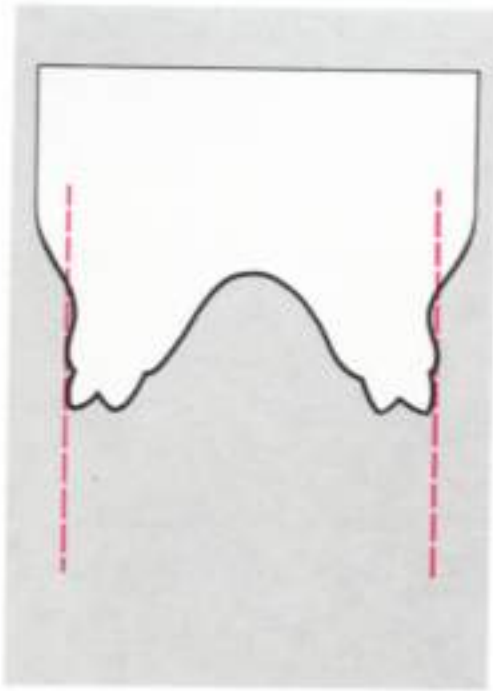
Any restriction of the supporting zones from the distal or the mesial results in an inadequate space for the unerupted permanent successional teeth (*Graber*, 1972).



86 Primary and secondary crowding
Anterior restriction of the supporting zones as a result of undermining resorption of the deciduous canines due to eruption of the lateral incisors. The supporting zone of the lower left quadrant is also reduced from the posterior due to mesial inclination of the first permanent molar after premature loss of the second deciduous molar.

The increased space between tooth 36 and tooth germ 37, when compared to the opposite side, is typical for a mesially migrated 6-year molar.

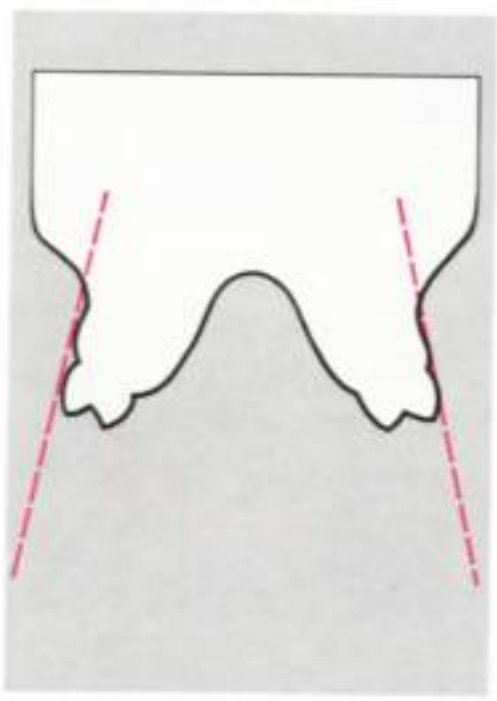




Apical base – Dental arch width

87 Configuration of a normal relationship
Occlusion of a female patient with a balanced relationship between the width of the dental arches and the transverse development of the apical bases.

Left: In such cases, the tangents running along the outer surfaces of the posterior teeth are parallel to one another (schematic view of a longitudinal section through the upper arch; *Schwarz*, 1961).



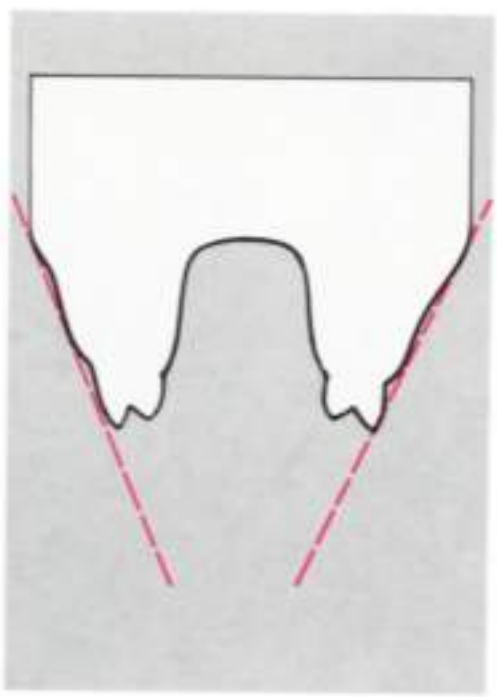
88 Disharmony in width of apical base and maxillary dental arch (apical crowding)
The upper posterior teeth are tilted buccally in comparison to their apical base.

Left: Cranially convergent tangents of the posterior buccal tooth surfaces imply that the basal bone is smaller than the dental arch.

An expansion of the dental arch is contraindicated with this type of crowding.

89 Constricted upper arch
The maxilla shown in Fig. 88, viewed from below.

Apical crowding with anteriorly constricted upper arch and anteroposterior lack of space for the second premolars.



90 Disharmony in width of apical base and dental arch due to a broad apical base
The apical base is wider than the dental arch and the posterior teeth are tipped lingually. The discrepancy is indicated by the interdental spacing.

Left: When the apical base is broader than the dental arch, the tangents of the posterior buccal surfaces converge occlusally.

In constricted dental arches with this type of coronal crowding an expansion therapy is indicated.

Vertical malpositioning of groups of teeth is judged in relation to the occlusal plane. "Supraversion" or "supraocclusion" indicates that the teeth have exceeded the level of the occlusal plane, "infraversion" or "infraocclusion" indicates that they have not yet reached it. This malpositioning usually occurs in conjunction with irregularities in the vertical development of the alveolar process.

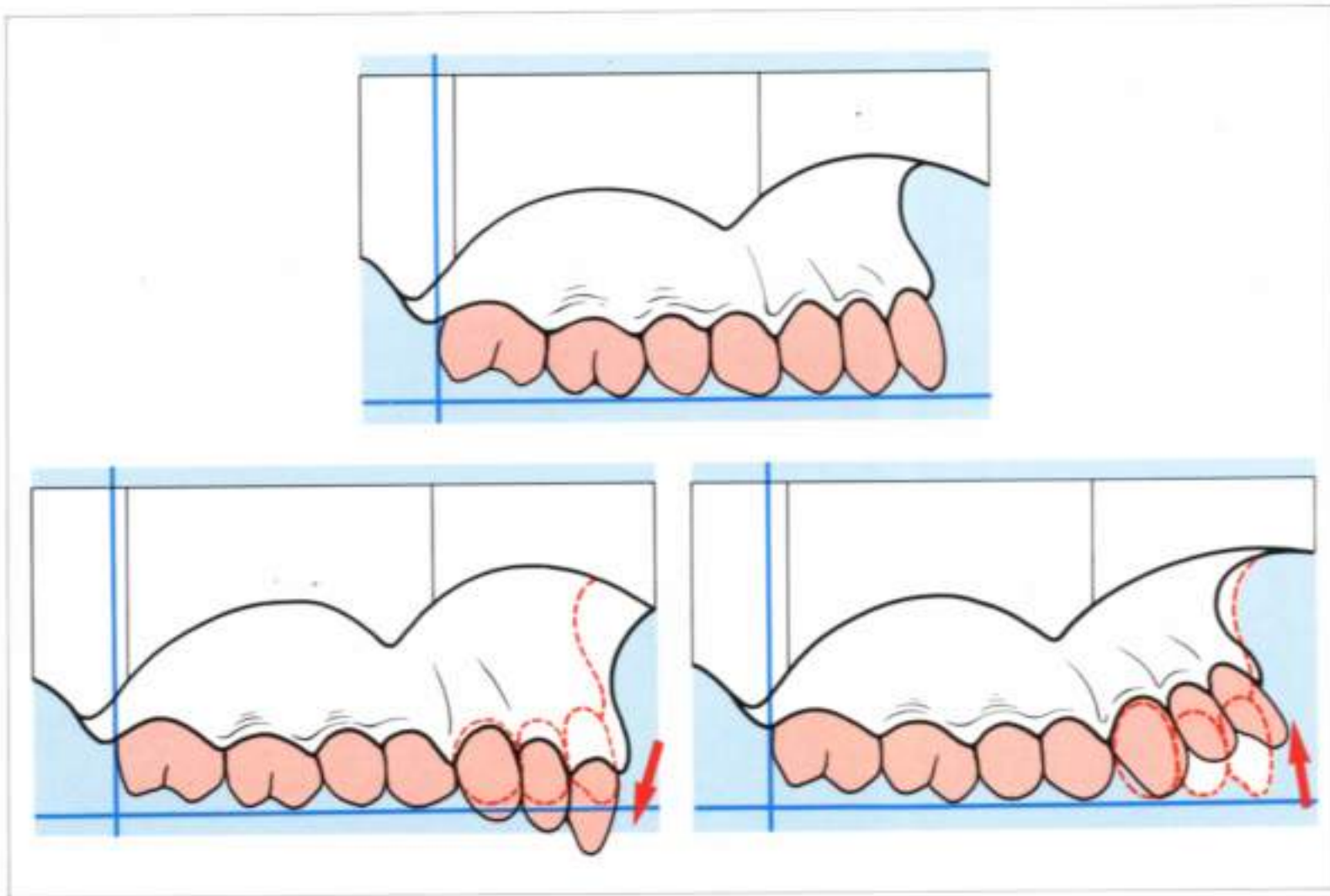
91 Vertical malpositioning of groups of teeth

Horizontal plane = Occlusal plane
Vertical plane = Tuberosity plane

Top: Correct vertical relation of the anterior and posterior teeth to the occlusal plane (the imaginary plane passes through the tips of the premolar cusps and is perpendicular to the tuberosity plane).

Bottom left: Supraversion of the upper anterior teeth with overextension of the anterior alveolar process.

Bottom right: Infraversion of the upper anterior teeth in conjunction with an underdeveloped anterior alveolar process (*Korkhaus*, 1939).



92 Supraocclusion of the anterior teeth

Supraversion of the upper incisors combined with a vertically overextended anterior alveolar process, and an excessive overbite.

93 Infraocclusion of the anterior teeth

Open bite malocclusion; the upper incisors do not reach the occlusal plane. The alveolar process is noticeably underdeveloped in the anterior region.

Note: An anterior open bite may also be due to an overeruption or supraocclusion of the posterior teeth.

Malocclusion

Sagittal:	Disto- and mesioclusion
Transverse:	Cross-bite, buccal nonocclusion, lingual nonocclusion
Vertical:	Deep bite, open bite

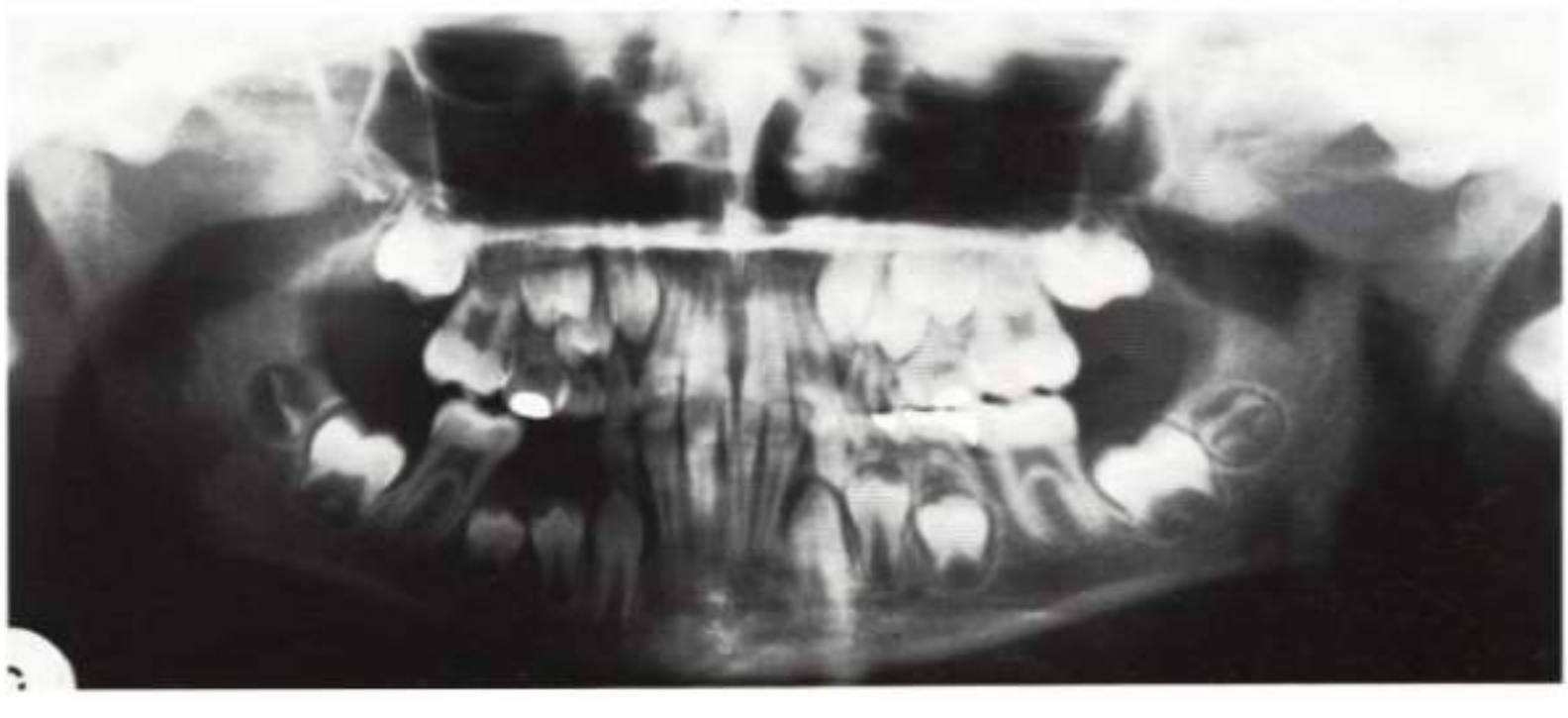
The traditional system for classifying malocclusions in anteroposterior direction dates back to Angle (1907). Angle assumed, wrongly, that the posterior occlusion and the sagittal jaw relationship coincide with one another. However, the intermaxillary relation of the posterior teeth, regardless of the skeletal jaw relation, may have been changed due to malpositioning of the upper or lower teeth (mesial migration, distal migration). When assessing sagittal variations from normal mesiodistal occlusion, it is important to differentiate precisely between the terms *"malrelationship of teeth"* and *"malrelationship of bony bases."* In order to determine the true anteroposterior basal bone relationships it is often necessary to visualize the positioning of the teeth prior to drifting. Exact reconstructions, however, are sometimes difficult.

Malocclusions of *cross-bite* can be due to the following:

1) Narrow upper jaw
2) and/or broad lower jaw:
   - bilaterally symmetric
   - bilaterally asymmetric
   - unilateral

When considering all types of *transverse anomalies,* including their prognoses and possible methods of treatment, one must differentiate between the dental and the skeletal components of the malocclusion. This differential diagnosis is especially important when assessing midline shifts.

Deep overbite anomalies are categorized into dentally supported deep overbites and gingivally supported deep overbites. *Open bite* anomalies are divided into anterior, lateral, and complex open bites, depending on the localization of the malocclusion (p. 145).



Occlusal relation – Jaw relation

94 Neutroclusion of the first molars, in a skeletal Class II malocclusion

The neutroclusion is a result of the mesial tilting of the lower first molar due to premature loss of the lower right deciduous molars.

Left: Radiographic view showing the mesial inclination of the lower right first molar. In order to reconstruct the jaw relationship, one must visualize the positioning of the teeth prior to the mesial drift taking place.

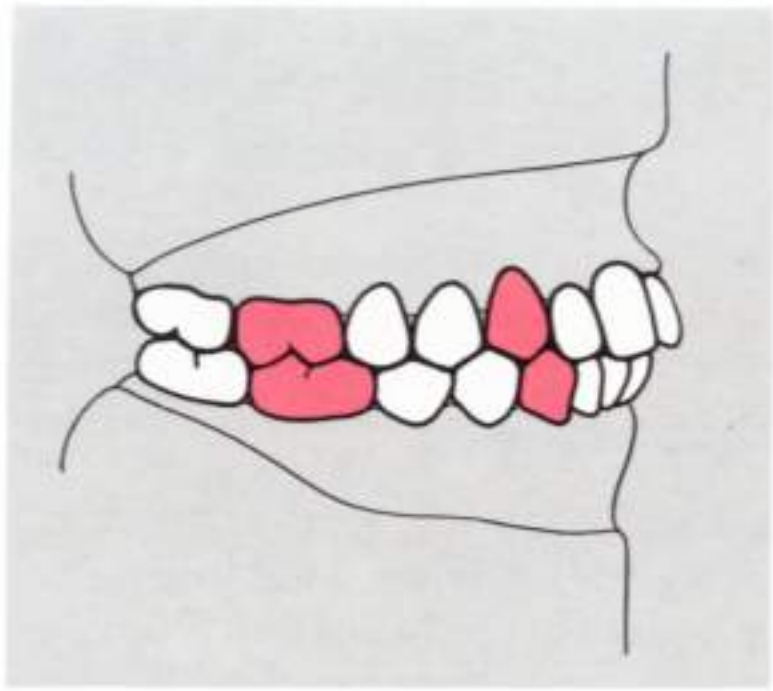
95 Bilateral mesial migration in the lower arch

Radiographic findings of the patient shown in Fig. 94. Premature loss of the lower right deciduous molars has caused both the lower right first molar and all teeth of the lower left arch to drift toward the space. Deviation of the lower midline toward the right is a symptom of this mesial migration.

Angle classification of malocclusion

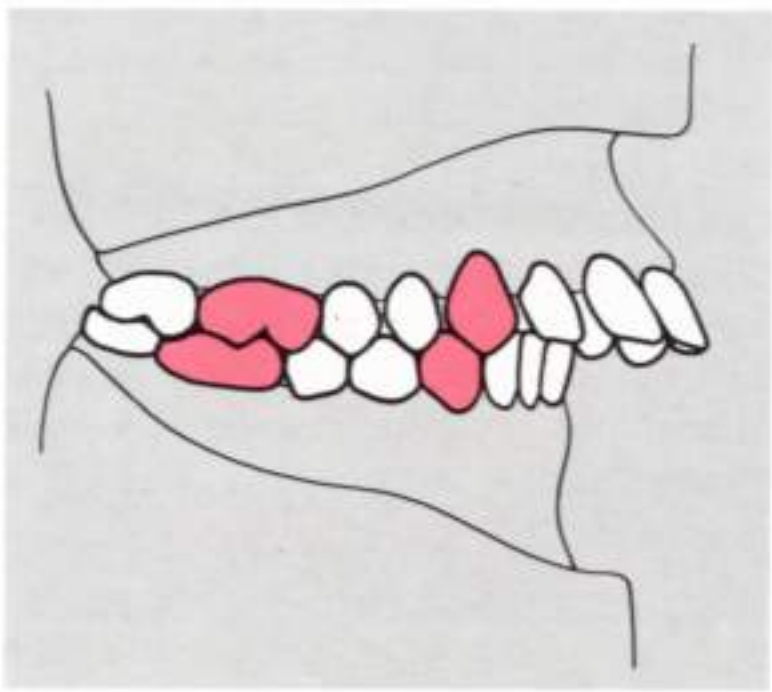
96 Angle Class I (neutroclusion, normal anteroposterior relationship)
Left: Occlusal relation in an Angle Class I case: The mesiobuccal cusp of the upper first molar interlocks with the mesiobuccal groove of the lower first molar.

Right: The cusp of the upper canine occludes half the width of a premolar behind the lower canine, between the tip of the canine and the tip of the first premolar cusp in the lower arch.



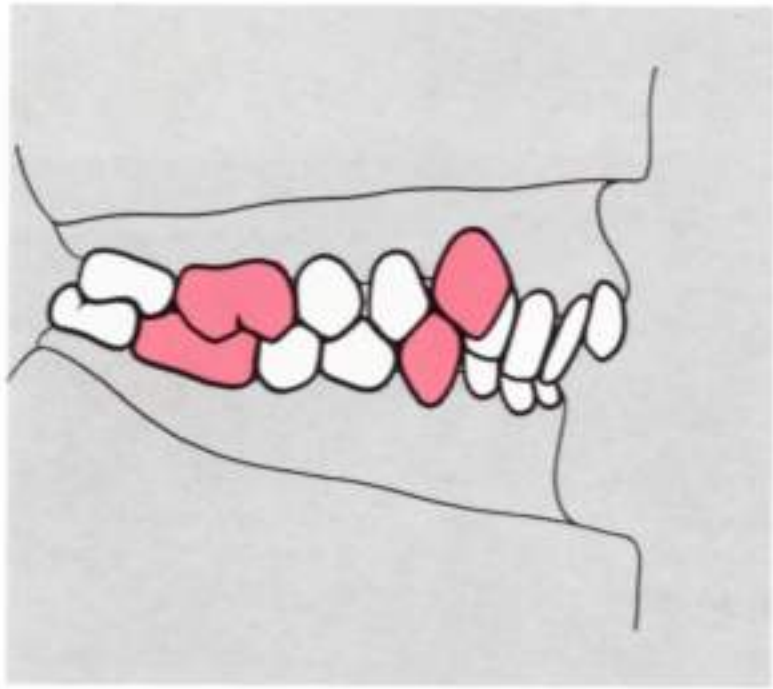
97 Angle Class II/Division 1 (distoclusion with labioversion of the maxillary incisors)
The lower dental arch is retruded in relation to the upper dental arch (the mandible is the reference point for this classification, assuming that the mandible is mobile via the TMJ).

Left: Diagram showing an Angle Class II/Division 1 malocclusion where the mandibular dentition is in a distal relationship to the maxillary dentition by the width of a premolar around the canines and first molars.



98 Angle Class II/Division 2 (distoclusion with linguoversion of the upper incisors)
Left: Diagram showing an Angle Class II/Division 2 malocclusion with a distal relationship of mandibular to maxillary dental arch by the width of a premolar.

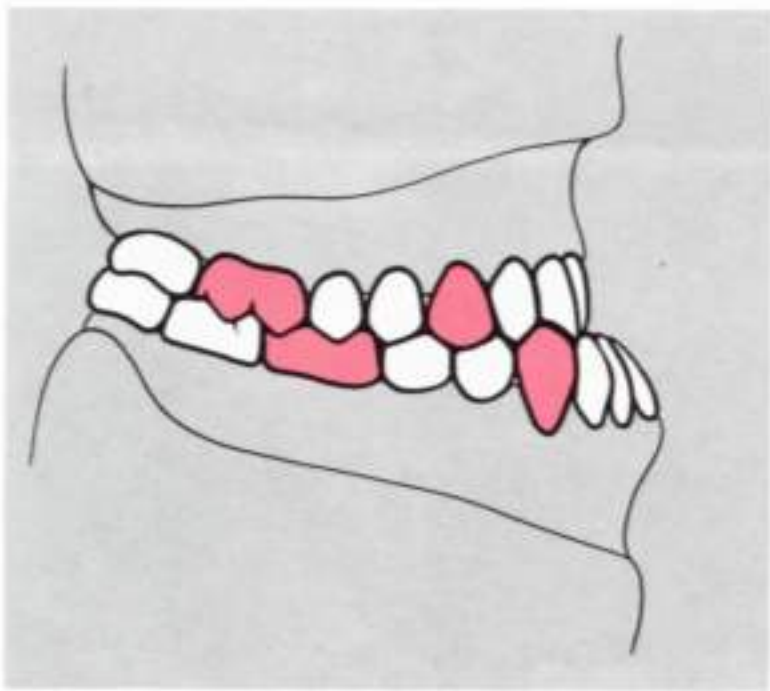
Right: The mandibular arch is in a posterior position by half the width of a premolar around the canines ("singular antagonism").



99 Angle Class III (mesioclusion)
The lower dental arch is in an anterior relation to the maxillary arch.

Left: Diagrammatic view of an Angle Class III malocclusion with anterior cross-bite. The mandibular dentition articulates in a relative anterior position by the width of a premolar.

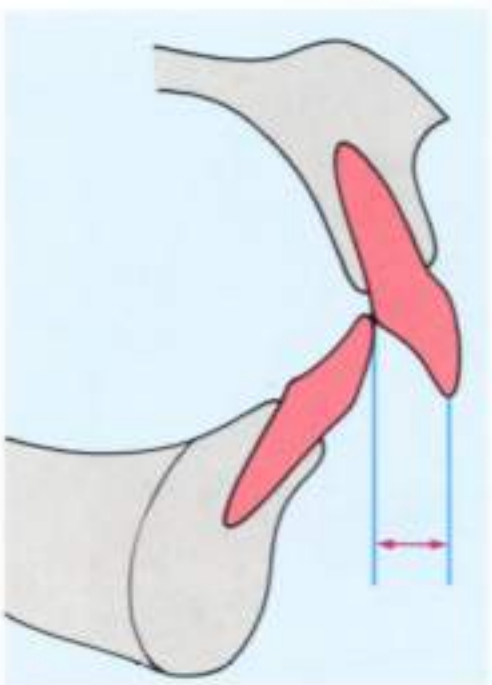
Right: The lower teeth are in a mesial relationship to the upper teeth by $^3/_4$ of the width of a premolar in the canine region.

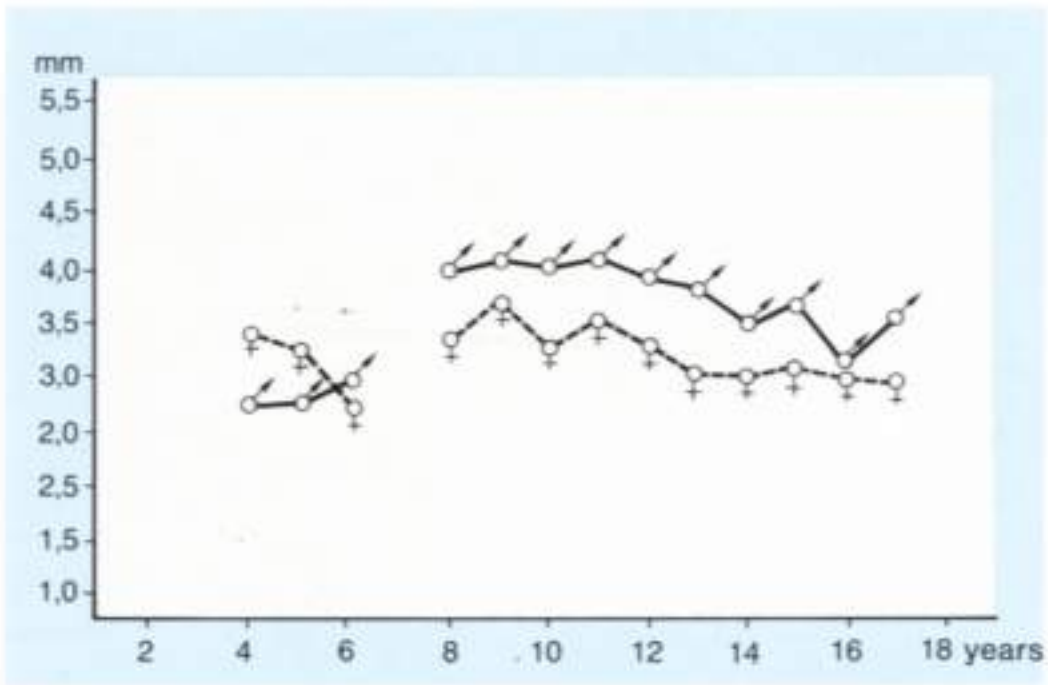


Overjet

The extent of overjet is determined primarily by the positioning of the upper and lower anterior teeth. Only in a minority of cases, the anteroposterior skeletal relationship is reflected directly by the amount of overjet. The mean value of the overjet in the "normal occlusion" is approximately 2 mm; being correlated to the labiolingual thickness of the upper incisal edge and the age of the patient (Fig. 100).

Depending on the direction and degree of abnormal labial/lingual inclination of the upper and lower incisors, different types of anterior malrelationship can be present with the same anteroposterior malocclusion. Should the sagittal dentoalveolar malalignment of the upper incisors coincide with that of the lower incisors, the overjet remains unchanged. Should this not apply, the overjet is either enlarged or reduced. Many clinicians connect irregularities of the overjet with an abnormal tongue and lip function or with a discrepancy in intermaxillary tooth-size between the upper and lower anterior arch.





100 Overjet
This term is defined as being the distance between the incisal edge of the upper central incisor and the labial surface of the lower central incisor.

Right: Graph showing the average changes, according to age, in the overjet of deciduous and permanent teeth, separately for boys and girls (*Moyers* et al., 1976).

101 Variations in overjet in Class II malocclusions
Left: Increased overjet, with the upper and lower incisors in correct axial inclination.

Center: Reduced overjet, with the upper anterior teeth in linguoversion and the lower incisors in correct axial inclination.

Right: Reduced overjet, with the upper anterior teeth in correct axial position and the lower incisors tipped labially.

102 Variations, depending on the position of lower incisors
Left: Increased overjet, with the upper anterior teeth flared labially and the lower incisors in correct axial inclination.

Center: Increased overjet, with the upper anterior teeth inclined labially and the lower incisors lingually.

Right: Slightly reduced overjet, with both the upper and lower anterior teeth in labioversion.

Vertical malocclusions – Deep bite

103 Excessive overbite – Deciduous dentition

The overbite is considered to be excessive when the incisors overlap by more than half.

Genuine deep bite in a deciduous dentition where the lower anterior teeth are covered completely as a result of an increase in height of the upper anterior alveolar process.

An excessive overbite may be encountered during any developmental period of the dentition.

104 Deep bite with Class III malocclusion

Deep bite in conjunction with mandibular prognathism and inverted overbite.

This vertical deviation can be related with any other anteroposterior or transverse malocclusion.

105 Length of clinical crowns

Deep bite in a patient with *long clinical crowns* of the incisors but without any increase in height of the anterior alveolar process.

106 Closed bite caused by loss of posterior teeth

Gingivally supported closed bite resulting from premature extraction of teeth in the mixed dentition.

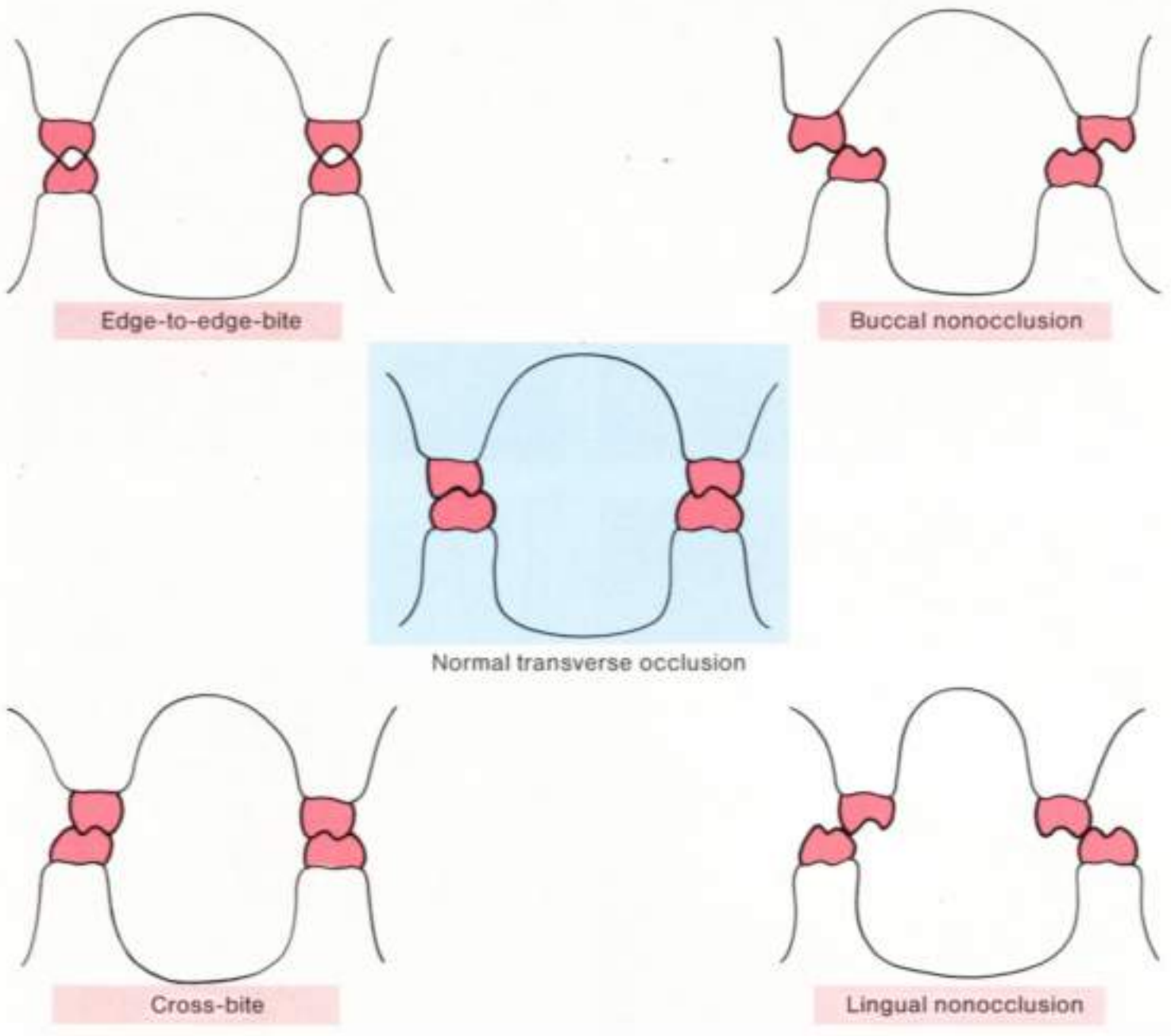
Pathogenetically, the closed bite is caused by an increased forward and upward rotation of the mandible, resulting from lack of posterior dental support.

Transverse malocclusions

107 Bilateral cross-bite
Class II malocclusion with a narrow upper arch.

The bilateral cross-bite is a result of the maxillary contraction.

Left: Longitudinal section through the models of a case with bilateral cross-bite and narrow upper arch.



108 Diagrammatic view of transverse occlusal deviations of the posterior segments

Center: Normal buccolingual relation. The cusp tips of the lower posterior teeth interdigitate with the central fossae of the upper posterior teeth.

Above left: Intermaxillary relation in case of a bilateral edge-to-edge bite and,
Above right: a bilateral, buccal nonocclusion.

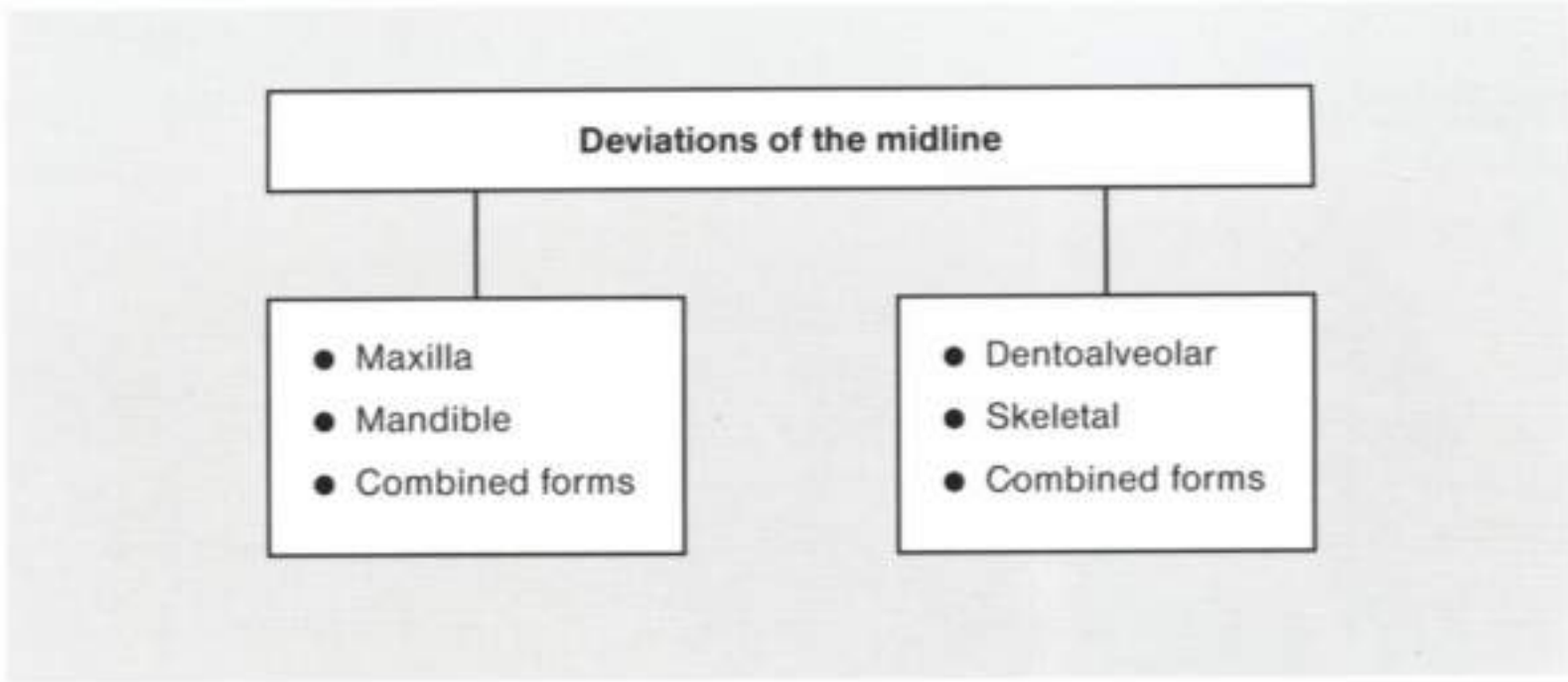
Below left: Occlusion in case of a bilateral cross-bite and,
Below right: a bilateral, lingual nonocclusion.

Transverse occlusal deviations can be either unilateral or bilateral. The individual malocclusions can be of different genesis.

109 Buccal nonocclusion
With this type of malrelationship, the upper posterior teeth occlude completely buccally of the lower teeth. The deviation is classified according to the position of the upper teeth.

Left: Longitudinal section through a case with bilateral, buccal nonocclusion caused by over-expansion of the upper arch.

110 Transverse malocclusions of the anterior region
Compilation of the various causal factors leading to the different forms of midline shift.



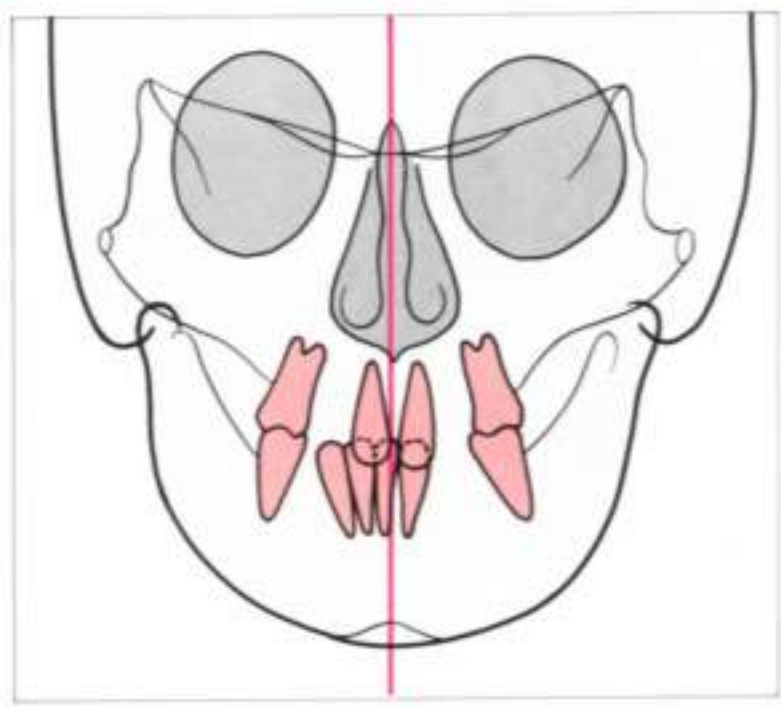
Midline deviation

111 Dentoalveolar midline shift in the upper arch
The upper central incisors have drifted toward the right, across the upper midline, due to the congenitally missing upper right lateral incisor.

Right: In cases of dentoalveolar drift, the contact point of the upper central incisors no longer coincides with the center of the philtrum.

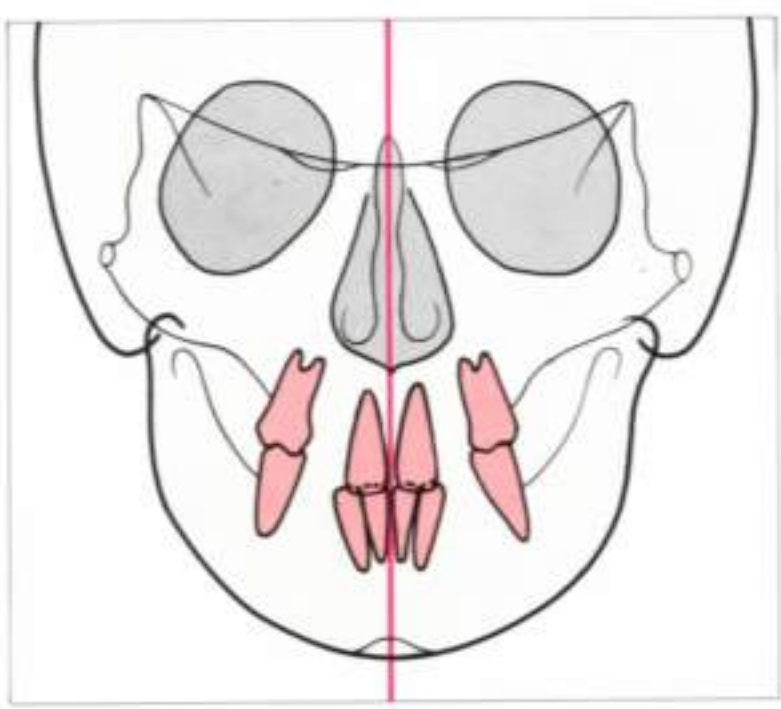
112 Midline shift in the lower arch
In the mandible, it is difficult to differentiate clinically between a dental midline shift (resulting from tooth migration) and a mandibular deviation resulting from a lateral jaw rotation of the bony base with asymmetric jaw development.

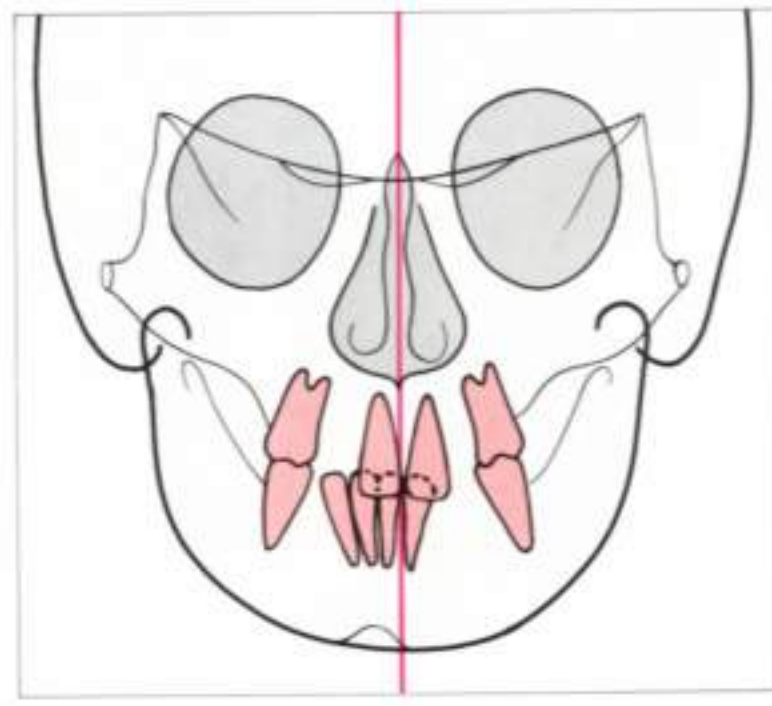
Right: Tracing of a PA cephalogram. In case of a dentoalveolar drift, the mental spine of the mandible coincides with the midsagittal plane of the skull and only the contact point of the lower incisors is deviated.



113 Skeletal deviation of the mandibular midline
Left: Diagram showing the normal morphologic relationships of the mandible in a PA cephalogram. The mental spine of the mandible and the contact point of the incisors coincide with the facial midsagittal plane.

Right: Relationships in case of a lateral deviation of the lower bony base. The skeletal midline of the mandible (mental spine) and the contact point of the lower incisors are displaced in unison.





Evaluating the Occlusion

During the 1970s, Andrews extended Angle's classification of "normal" intercuspation. He reformulated the static prerequisites for optimal equilibrated occlusion and called them the "six keys of occlusion," based on the analysis of the tooth material, in particular tooth crown morphology.

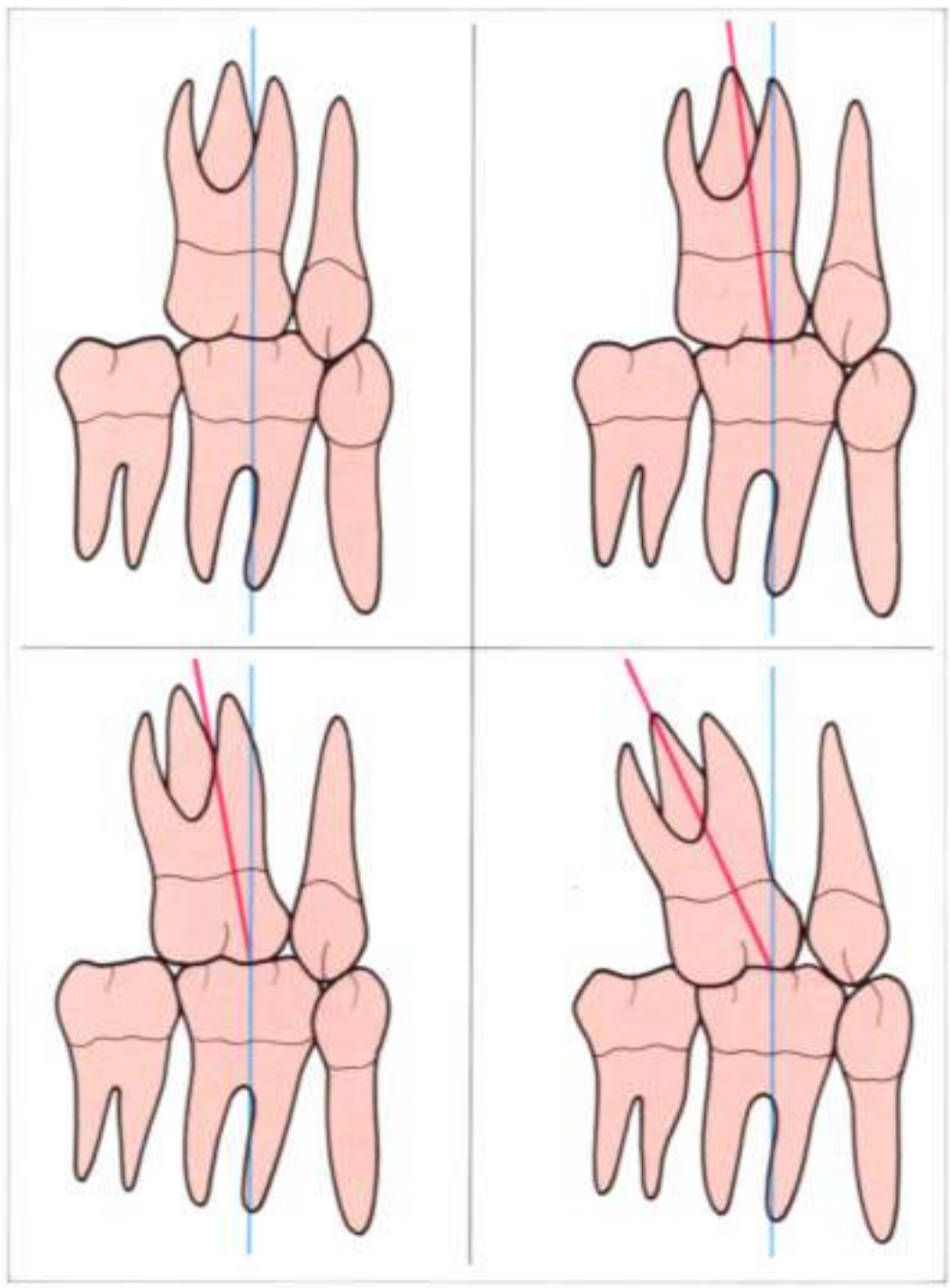
Unlike the classic parameter of assessment, the long tooth axis which takes the root inclination into account, the basic criteria of this extended occlusal diagnostic concept is the *long crown axis* of the tooth and the *occlusal plane.*

Both parameters can be recorded directly during the clinical examination or on the study cast and do not require further, expensive, time-consuming or radiographic diagnostic procedures (e.g. cephalometric radiographs). A further advantage of this type of analysis is that the long axes can be determined individually for the various types of teeth.

The occlusion is evaluated according to the following keys:

The six keys of normal occlusion

1) Molar interarch relationship
2) Mesiodistal crown angulation
3) Labiolingual crown inclination
4) Rotations
5) Tight contacts
6) Occlusal plane (curve of Spee)



114 The first key of normal occlusion: Molar interarch relationship

Above: Diagram showing examples of occlusions with poor Class I molar relationships, according to Andrews, caused by insufficient crown angulation of the upper first molar.

Bottom left: Diagram showing an improved Class I molar relationship.

Bottom right: Diagram showing the correct Class I molar relationship according to Andrew's first key of occlusion.

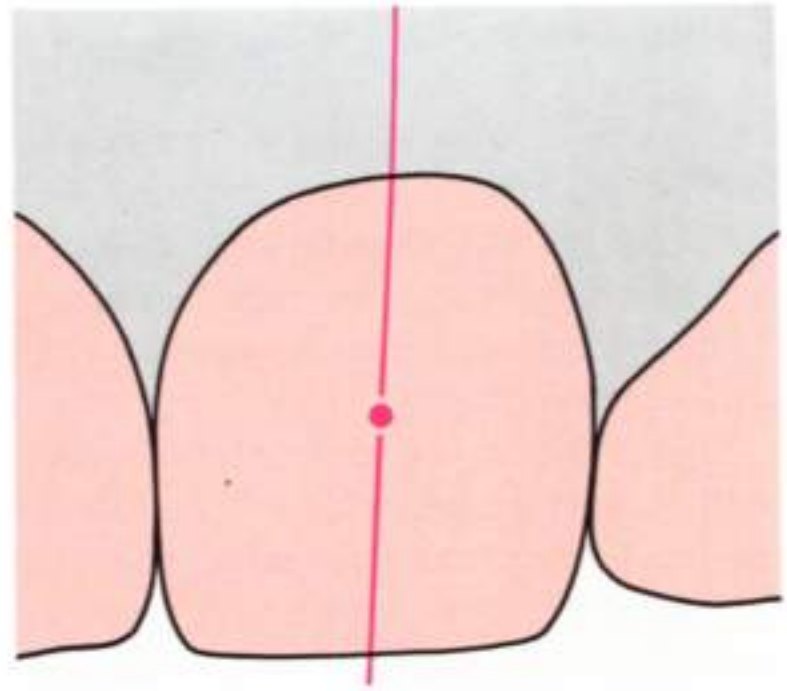
According to Andrew's occlusal concept:

- The mesiobuccal cusp of the upper first molar should occlude in the groove between the mesial and medial buccal cusp of the lower first molar.
- The mesiolingual cusp of the upper first molar should occlude in the central fossa of the lower 6-year molar.
- The crown of the upper first molar must be angulated so that its distal marginal ridge occludes with the mesial marginal ridge of the lower second molar (*Andrews*, 1972).

115 Long axis of the crown

Vertical line = Long axis of the clinical crown (= LACC)
LA spot = Center of the long axis of the clinical crown

Unlike other concepts, it is not the long axis of the tooth which serves as the plane of reference, but rather the long axis of the clinical crown. It passes through the central, vertical ridge of the tooth, i.e. through the most prominent part in the center of the labial or buccal surface. This applies to all teeth, except molars.

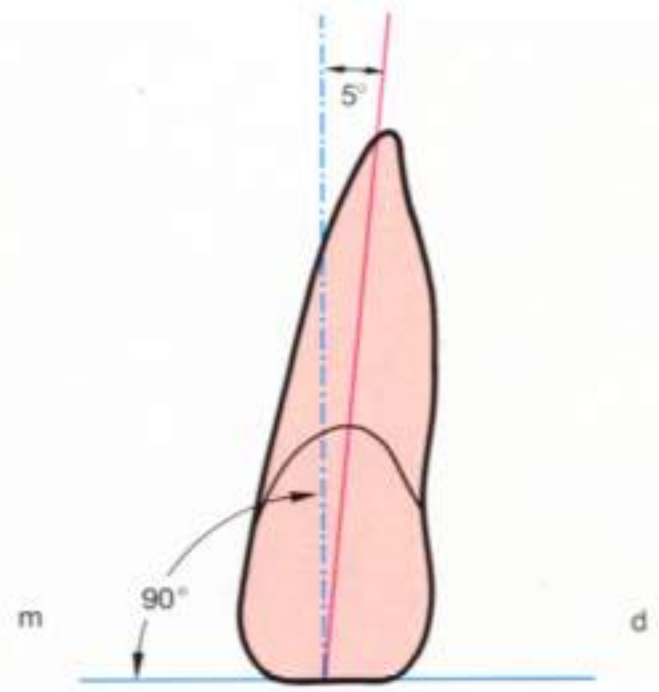


116 Mesiodistal angulation of the crown

--- Perpendicular to the occlusal plane
—— Long axis of the crown

The angulation of the crown is defined as the angle which the tooth forms with a line drawn perpendicular to the occlusal plane.

Right: Drawing showing the mesiodistal angulation of the crown of the upper left central incisor (*Andrews*, 1972).

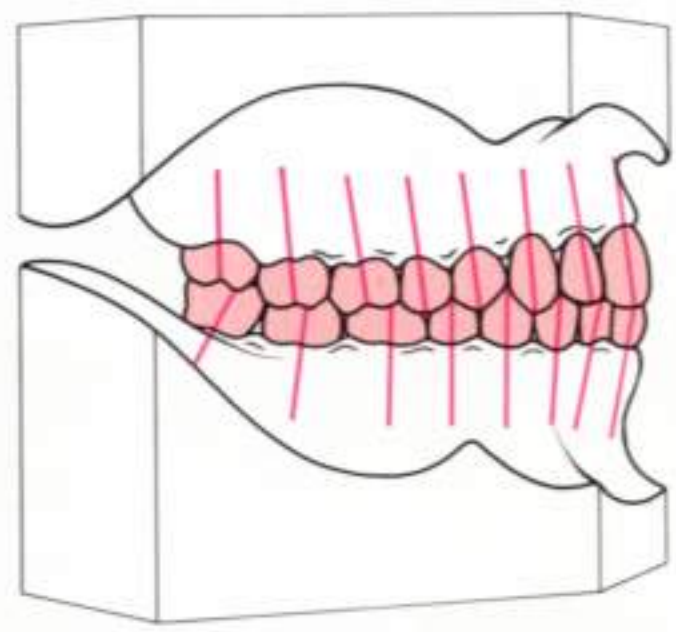


117 Second key of normal occlusion: Mesiodistal crown angulation

For the occlusion to be considered normal, the gingival part of the long axis of the crown must be distal to the occlusal part of the axis.

The degree of angulation depends on the type of tooth.

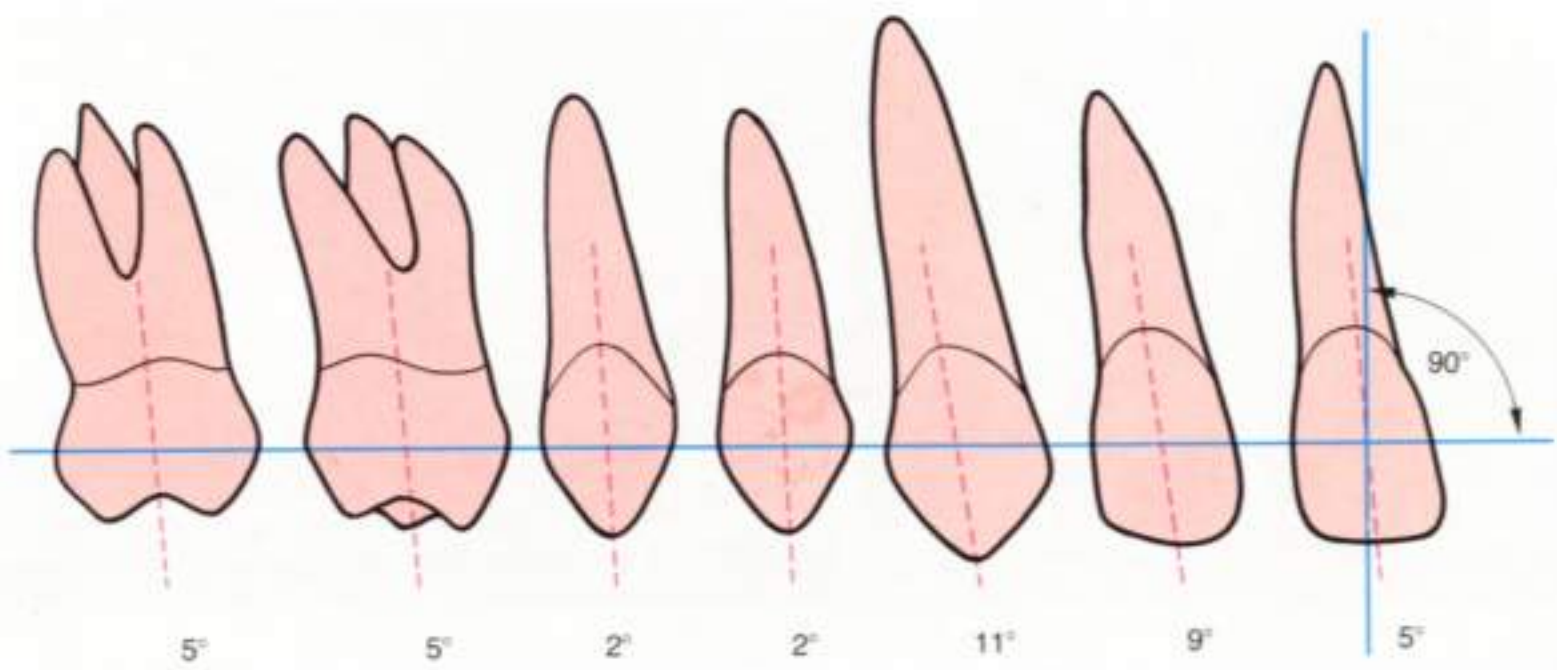
Right: Diagrammatic view of the mesiodistal angulation of the crowns when the occlusion is normal (*Andrews*, 1972).

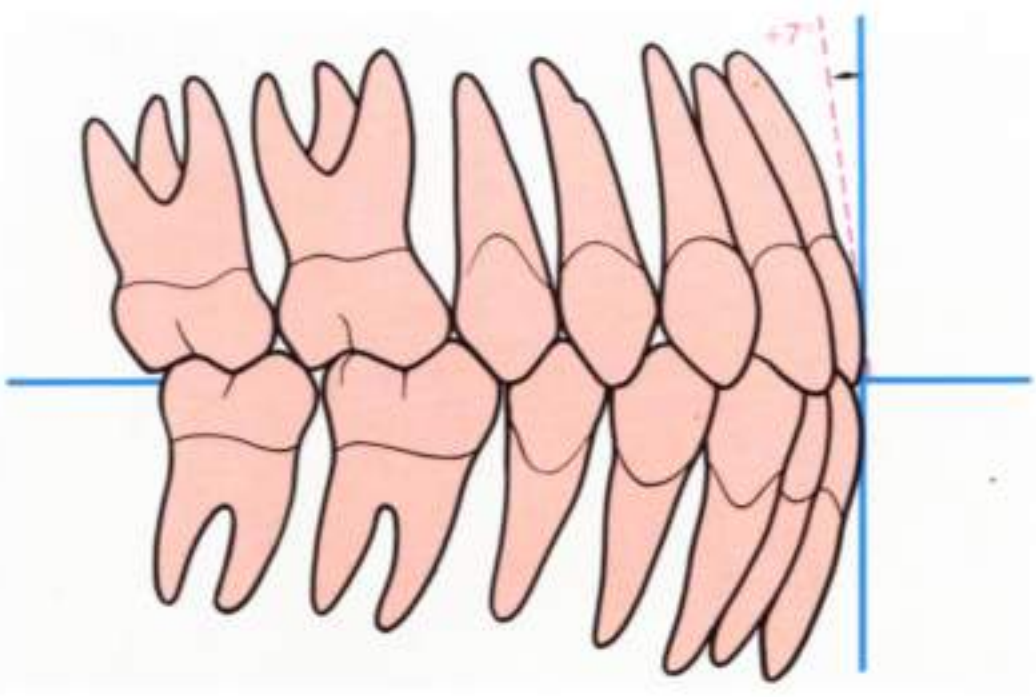


118 Mesiodistal crown angulation for various types of upper teeth

Horizontal plane of reference = Line passing through all LA spots (Andrews plane)
Vertical plane of reference = Perpendicular to the horizontal plane

According to Andrews, in the upper jaw the crowns of the canines exhibit the greatest degree of angulation and the premolars the least.



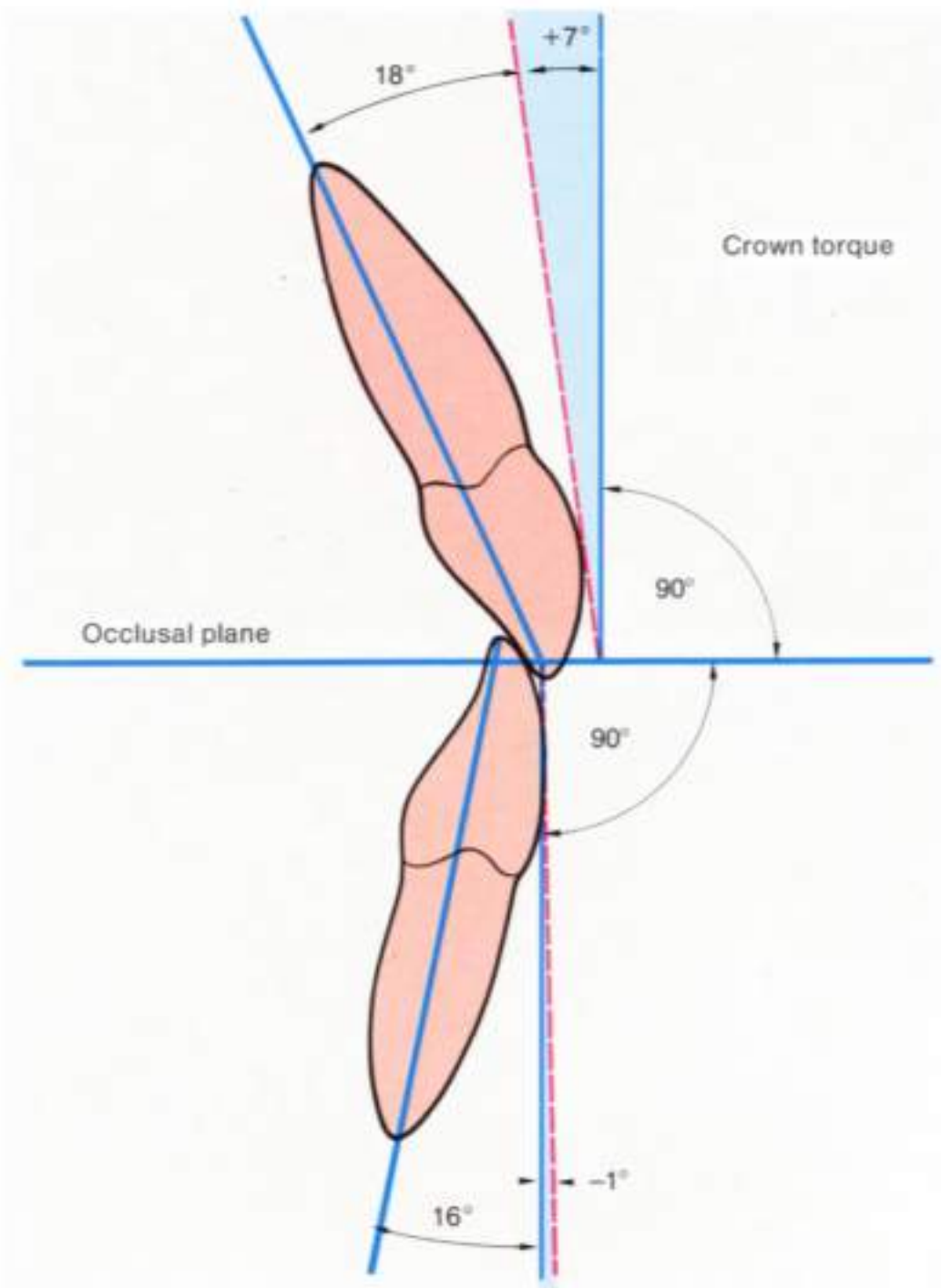


119 Third key of occlusion: Labiolingual crown inclination

--- Tangent on the crown of the tooth
—— Perpendicular to the occlusal plane

The third key defines the angle between a tangent to the LACC at its center and a line perpendicular to the occlusal plane.

If the gingival area of the crown is more toward the lingual, the result is expressed in positive values; should the opposite apply, the result is negative.

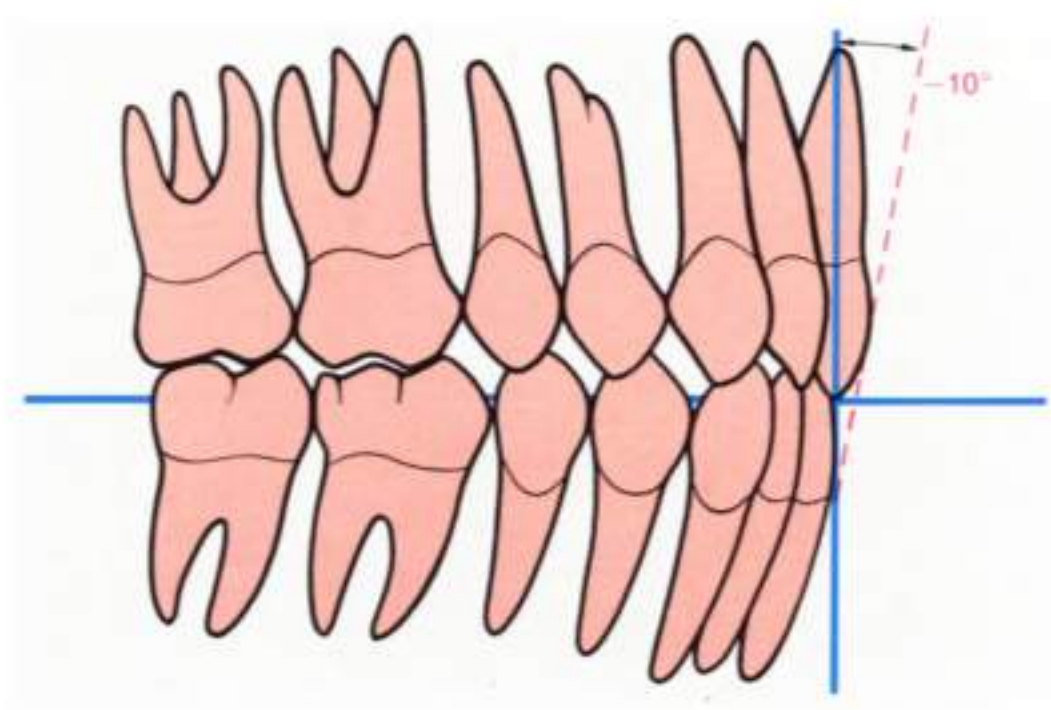


120 Labiolingual crown inclination between upper and lower incisors (crown torque)

--- Tooth crown tangent
—— Perpendicular to the occlusal plane
▬ Long axes of the incisors

The upper incisors form a positive angle with the crown tangent and the line perpendicular to the occlusal plane (+ 7°) and an angle of 18° between the crown tangent and the long axis of the tooth.

The crown torque of the lower incisor is – 1° and the angle between its crown tangent and the axis of the incisors is 16°. The interincisal angle between the crown tangents of the upper and lower incisors is 174° for normal occlusions (unlike the interincisal angle between the axes of the incisors which is considered to be, on average, 139°) (*Andrews*, 1972).

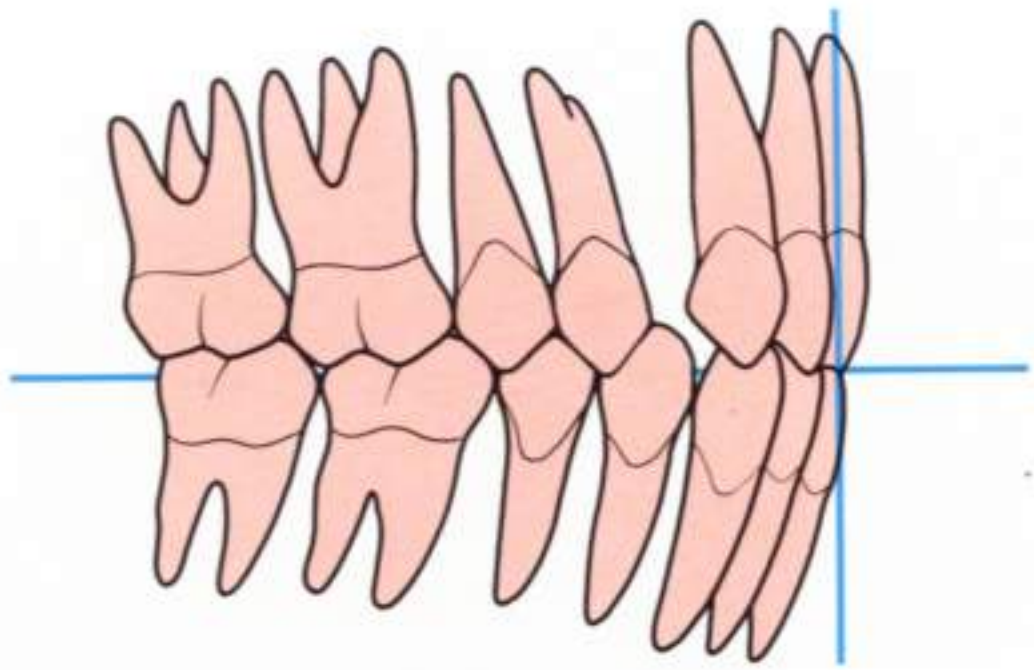


121 Incorrect crown torque and occlusal findings

Should the upper anterior teeth be in a too upright position (the labiolingual crown inclinations of the upper incisors have negative values), the occlusion is unstable. The canine guidance is insufficient and there is a risk that the posterior teeth will drift toward the mesial (*Andrews*, 1972).

122 Anterior and posterior occlusion in case of incorrect crown torque

If the posterior occlusion is correct, but the upper incisors are in linguoversion, this can result in interdental spacing of the anterior teeth which then is often incorrectly associated with a discrepancy in the intermaxillary tooth-size (*Andrews*, 1972).



123 Occlusal changes after orthodontic treatment

Clinical picture of the situation schematically shown in Fig. 122. Occlusal relations in the postretention stage after orthodontic treatment.

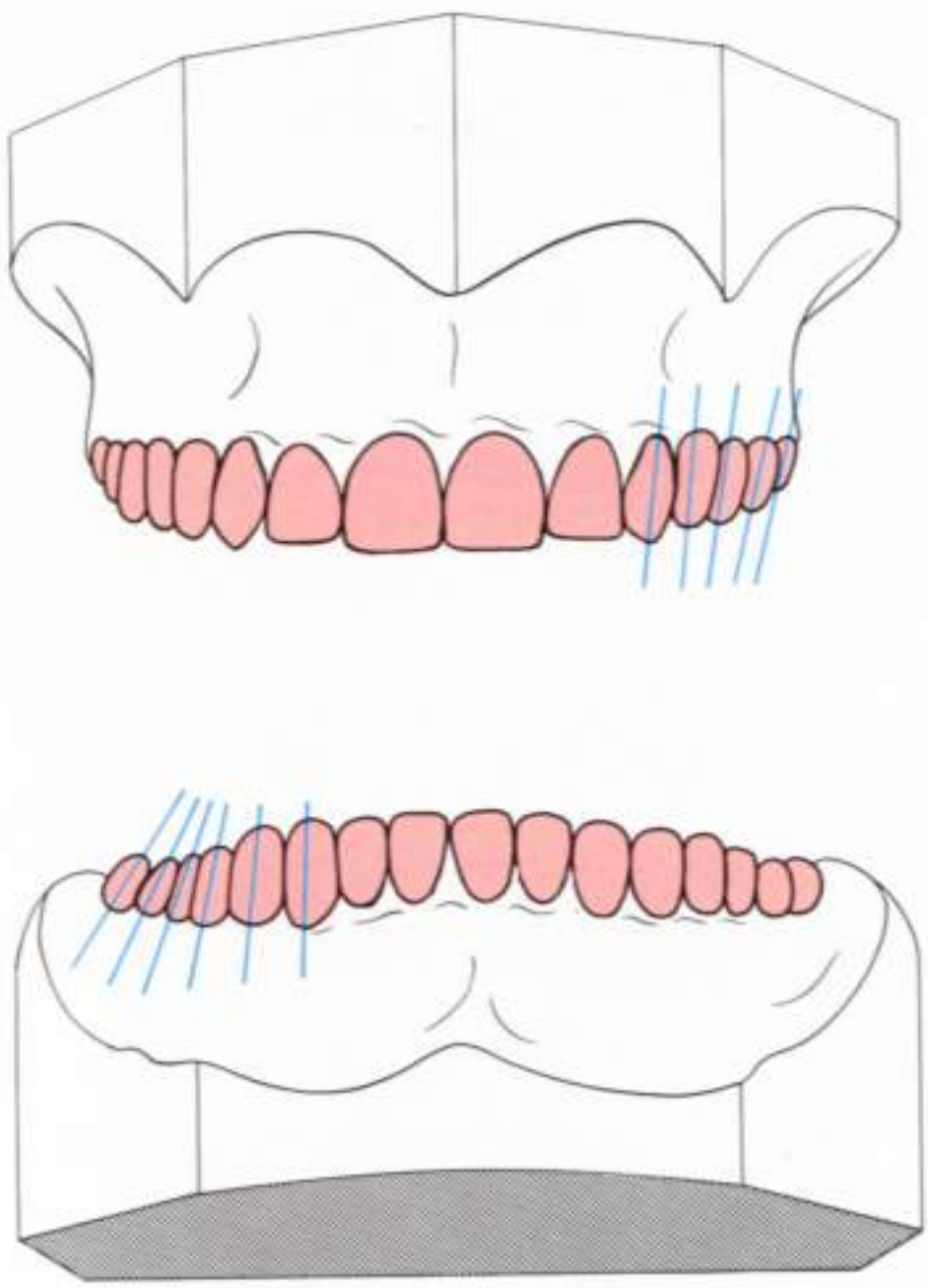
The long-term result is a dentally supported bite with lingually inclined upper incisors and a space posterior to the upper right canine. The canines are no longer in Class I relationship.

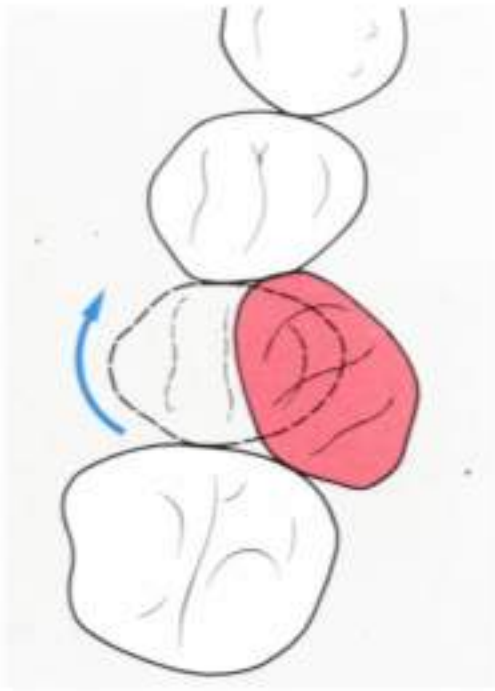
124 Labiolingual inclination of the posterior teeth in optimal occlusion

The tangents on the facial surfaces of the crowns form negative values with the line drawn perpendicular to the occlusal plane, i.e. the gingival portions of the teeth are more pronounced buccally than the occlusal portions.

The upper canines and premolars are inclined at virtually the same angle, whereby the molars are tilted slightly more.

In the lower arch, the inclination increases progressively from the canine to the second molar.





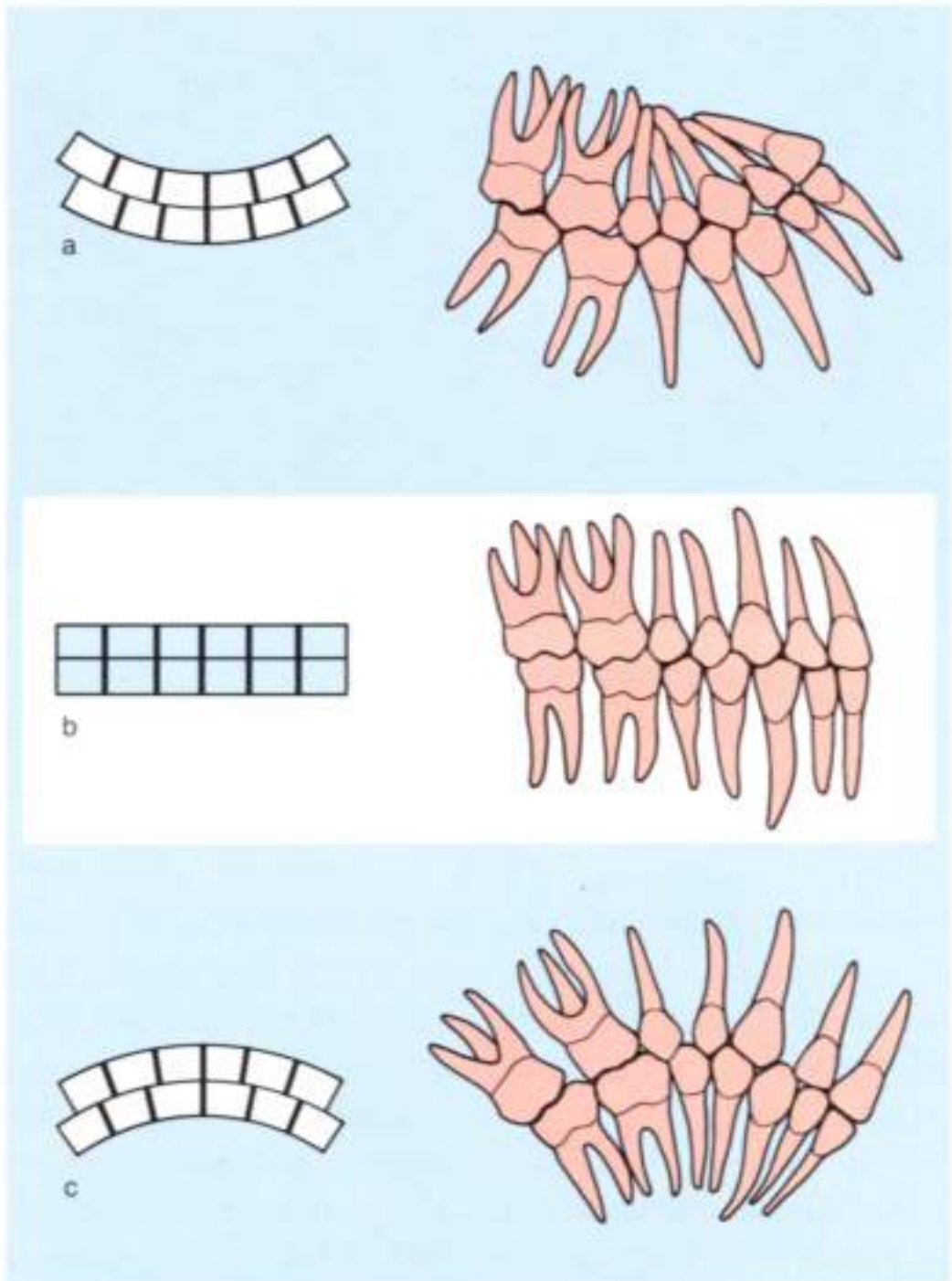
125 Fourth key of occlusion: Rotations

In order to achieve correct occlusion, none of the teeth should be rotated. Rotated molars and premolars occupy more space in the dental arch than normal. Rotated incisors may occupy less space than those correctly alignd. Rotated canines adversely affect esthetics and may lead to occlusal interferences.

126 Fifth key of occlusion: Tight contacts, no spacing

If there are no anomalies in the shape of the teeth, or intermaxillary discrepancies in the mesiodistal tooth size, the contact points should abut in normal occlusion.

Clinical picture of a poor example, with spaces between the upper teeth and a Class I relationship of the canines. These findings are indicative of a Bolton discrepancy (refer to p. 228).



127 Sixth key of occlusion: Curve of Spee

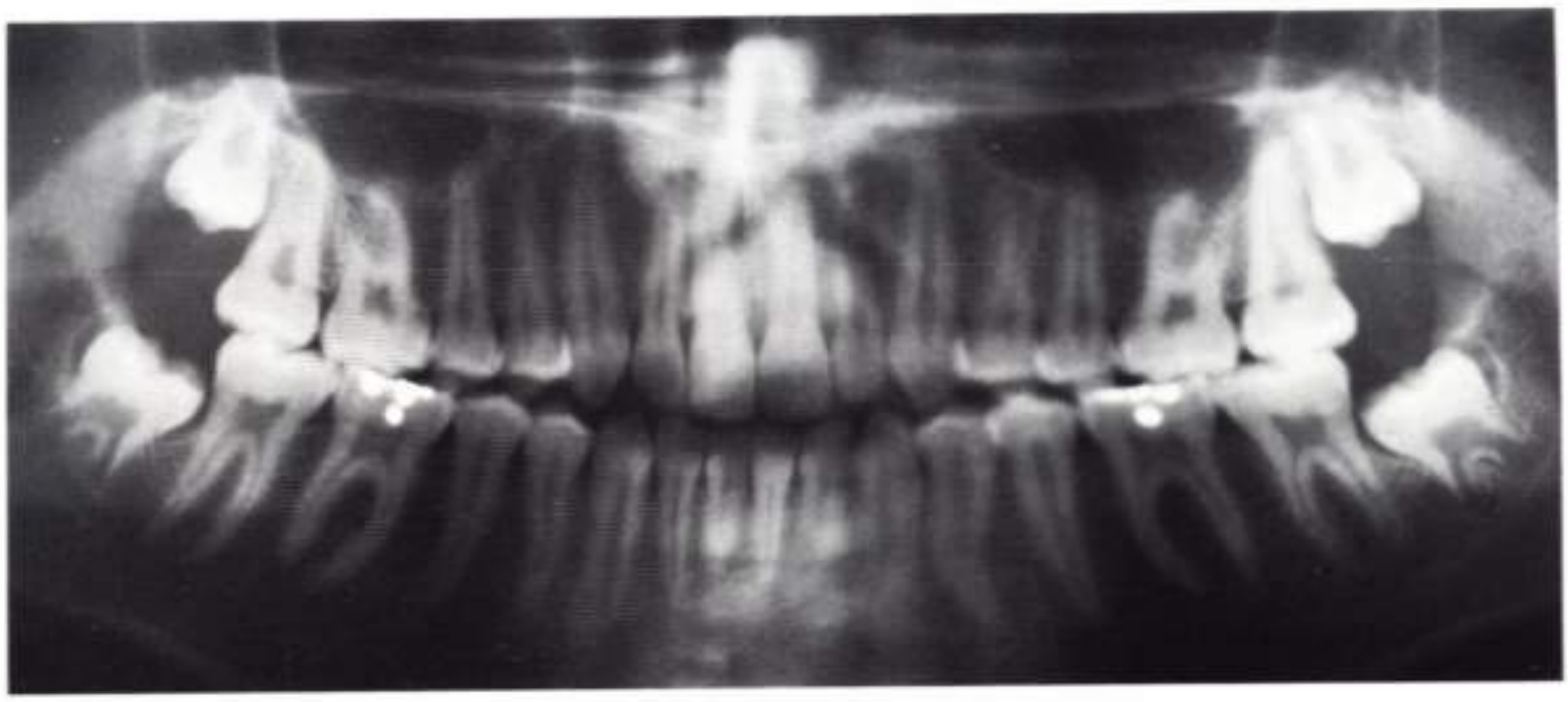
a An excessive curve of Spee restricts the amount of space available for the upper teeth, which must then move toward the mesial and distal, thus preventing correct intercuspation.

b A normal occlusion has a flat occlusal plane (according to Andrews, the mandibular curve of Spee should not be deeper than 1.5 mm).

c A reverse curve of Spee creates excessive space in the upper jaw, which prevents development of a normal occlusion (*Andrews*, 1972).

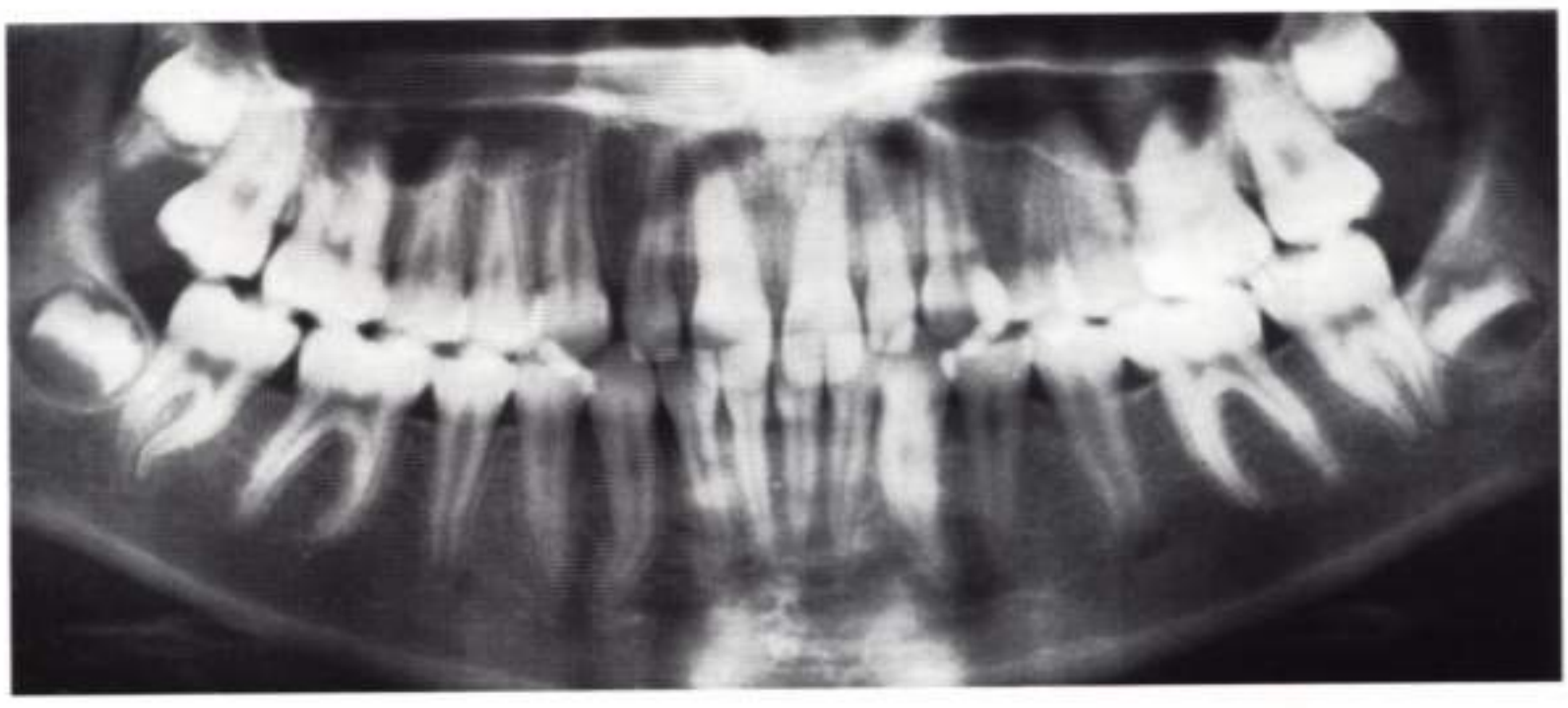
Curve of Spee – Occlusion – Case examples –

128 Reverse curve of Spee
This panoramic radiograph shows the occlusal relationship resulting from a reverse sagittal compensating curve. When compared to the upper jaw, insufficient space is available in the lower dental arch and the anterior teeth are crowded. The bite is open anteriorly.



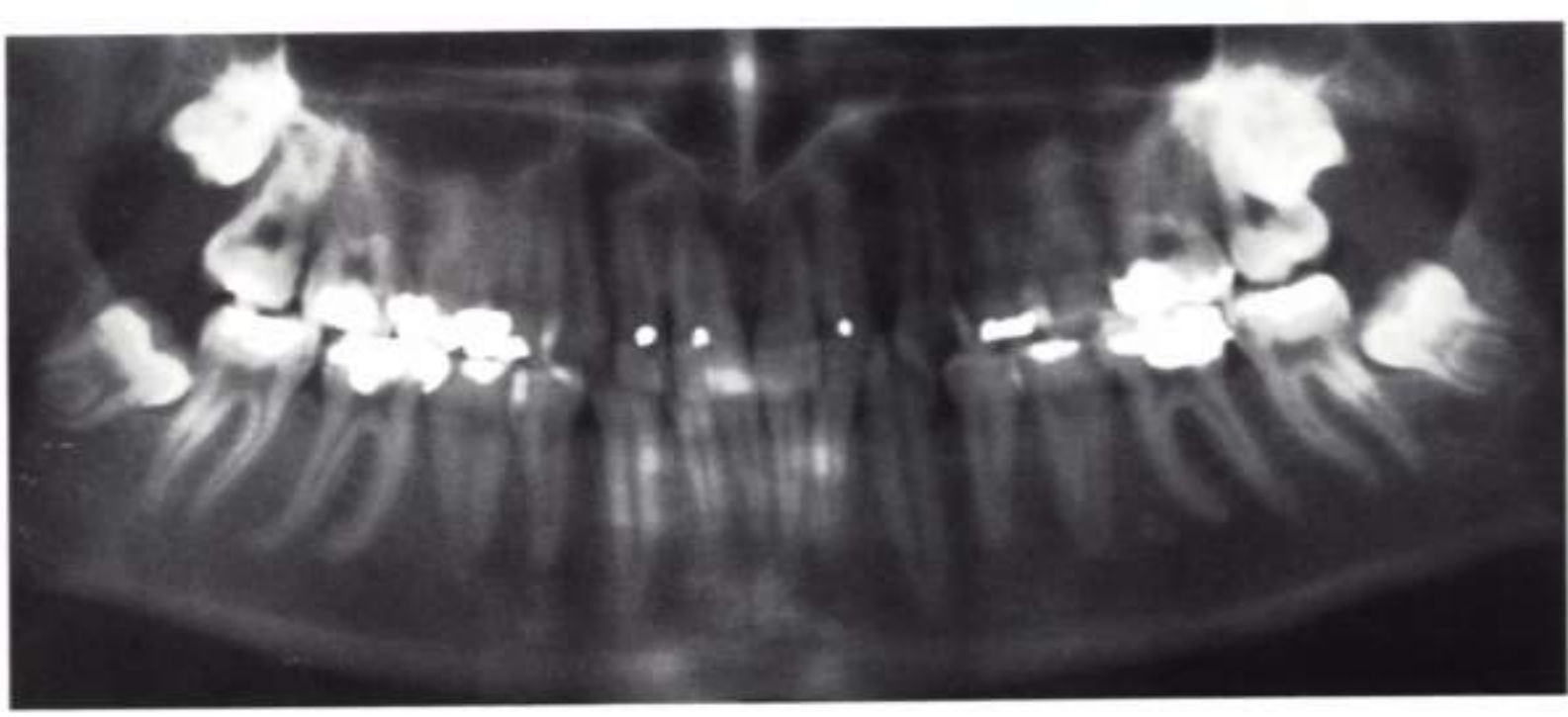
129 Flat curve of Spee
Flat sagittal compensating curve with good intercuspation around the premolars and molars.

This type of curve is considered to be "normal" according to Andrews.



130 Excessive curve of Spee
Pronounced sagittal compensating curve with excessive space in the upper dental arch and inadequate space in the lower arch.

The lower incisors are crowded and the overbite is increased.

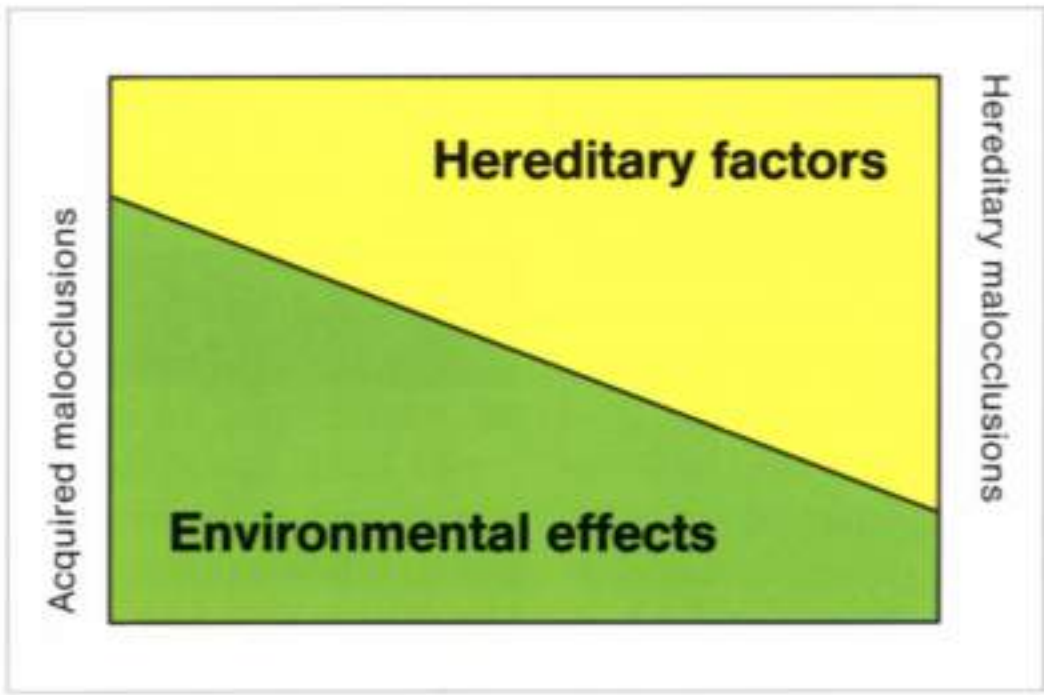


Etiology of Malocclusion

Etiological assessment of malocclusion is an important aspect in orthodontics, as the genesis of the deformity provides keys to the planning of treatment. The developmental process of dentition and craniofacial growth takes place over a period of approximately 20 years, whereby the environment has a modeling impact on the genotype, being an integral part of the factors of heredity. Due to this interaction, it is difficult to classify the etiology of malocclusion exactly, as the causes are often multifactorial and prevent exact differentiation between endogeneously and exogeneously induced changes.

According to the current level of etiologic research, the inherited pattern of malocclusion is usually not monogenic, but rather polygenic, i.e. the single gene which plays a role in expressing the characteristics (i.e. the malocclusion in orthodontics) only has a slight effect on the specific manifestation in the phenotype.

Only the accumulative effect of the various numbers of genes involved determines the inherited traits.



131 Etiology of malocclusion
Comparison of the two different determining factors in the genesis of dentoalveolar and skeletal malocclusions.

Therefore, polygenic characteristics or malocclusions do not have such a definite clinical appearance as monogenic ones (e.g. hereditary enamel dysplasia), which can be distinguished by their relatively standardized phenotype.

The etiology of malocclusion is mostly based on a *multifactorial system with "additive polygenesis" and threshold effect,* i.e. in order to become a distinctive factor in the phenotype, the inherited bundle of genes can be "tipped over the edge" for instance by environmental factors (Jörgensen, 1966). Depending on the genetic constitution, the exogenous influences must be mild to severe for expressing the character of the deformity in a more pronounced form. On the other hand, they can also camouflage a deformity if they oppose the hereditary factors (Figs. 132–134).

The *exogenous influences* can be either *systemic or localized.* Whereas systemic factors such as climatic or ecological conditions, nutrition, and diseases can influence the overall development of the human organism, local factors in the etiology of malocclusions have an effect on the masticatory system only.

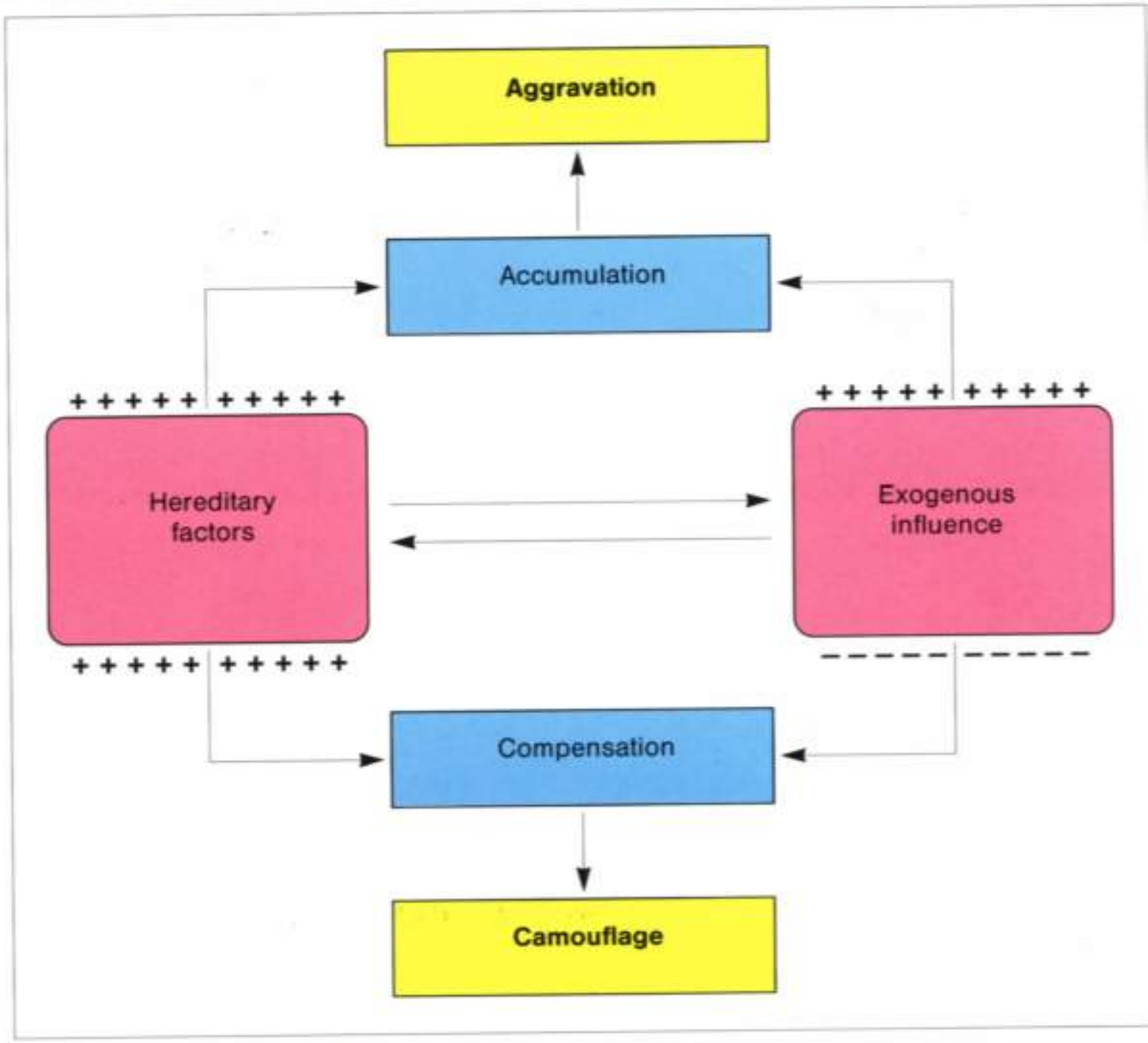
The exogenous influences can be of a *static* or *functional nature.* Static factors have an effect on only one specific site or are only active once (trauma).

132 Aggravation of traits in the phenotype
Clinical findings of an 8-year-old patient with hereditary mandibular prognathism (Class III).

Right: The malocclusion, i.e. impeded development of the upper jaw, was exacerbated due to premature loss of the deciduous teeth and early extraction of the upper left permanent molar.

133 Interaction between hereditary factors and exogenous influences
If, in the etiology of malocclusions, the exogenic influences take place in the same direction as the hereditary factors, the resulting accumulative effect leads to aggravated characteristics in the phenotype.

Vice versa, the traits of the genotype can be masked by the effect of environmental factors.



134 Camouflage of hereditary factors
An open bite due to thumb-sucking and tongue-thrust in a 4-year-old female patient.

Right: 1 year after eliminating the exogenous influences (termination of the dysfunctions), the genetic predisposition to dental crowding becomes apparent.

Causes of Malocclusion

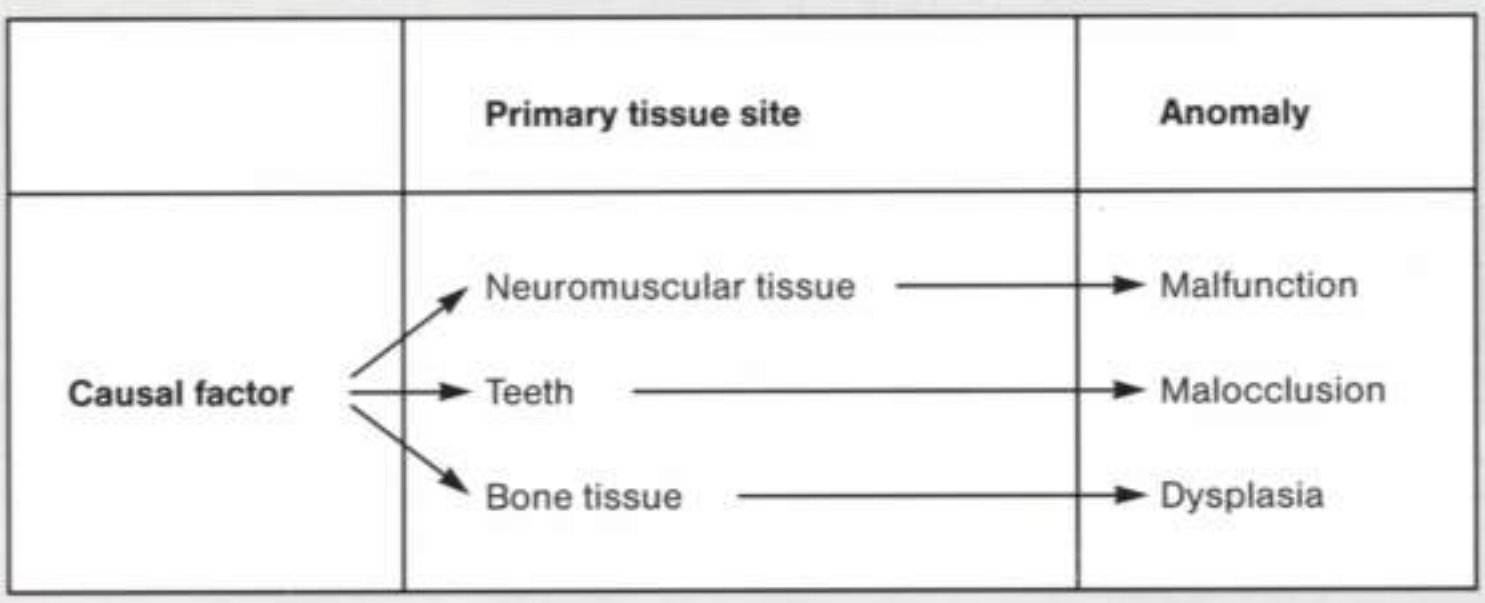
As it is not possible to classify dentofacial anomalies precisely, their most common original causes have been summarized in seven groups (Dockrell, 1952):

Cause → acts for a specific period of	time → on a particular	tissue → producing	results
1) Hereditary 2) Anomalies due to maldevelopment 3) Trauma 4) Physical agents 5) Habits 6) Disease 7) Malnutrition	1) Continual, intermittent, or only once 2) Various age levels (pre- or postnatal)	1) Neuromuscular tissue 2) Teeth 3) Bone 4) Cartilage 5) Soft tissue, except muscles	1) Malfunction 2) Malocclusion 3) Bone dysplasia

Each *causal factor* primarily affects a particular tissue for a certain period of time, which causes the deformity (see above). As far as the time factor is concerned, the specific cause can act continual, intermittent, or operate only once, in any or all developmental stages (pre- or postnatal).

The results of these disruptive factors depend on the localization and texture of the tissue most affected by the deformity. The primary tissue site may be: the *neuromuscular tissue*, the *teeth*, the *bones*, the *cartilage tissue*, and the other *soft tissues*, except the muscles (see above).

The primary deformities caused by these factors are: malfunction, should the neuromuscular tissues be affected primarily; malocclusion, should the teeth be affected primarily; and osseous dysplasia, should the bone tissue be affected primarily (Fig. 135).



135 Causal pathogenesis of anomalies
The etiology of a dentofacial defor mity is determined by the type o tissue which is primarily affected by the causal factor.

In many cases, a combination o all three anomalies occurs as, apar from the primary tissue site the other tissues, are usually second arily also involved in the deformity

Hereditary Abnormalities

For a long time, inheritance was considered the most important causal factor in the genesis of dentofacial deformities, although there is nearly no scientific evidence to support this thesis. Exact details about the significance of hereditary factors in the etiology of malformations can only be gained by carrying out extensive studies on twins and families. According to current knowledge, the following tissues can be primarily affected by genetically transferred dentofacial deformities:

- Neuromuscular system
- Teeth
- Bone/cartilage tissue or
- Soft tissues

Neuromuscular System

Hereditary deformities of the neuromuscular system consist primarily of anomalies in

size, position, tonicity, contractility, and in the *neuromuscular coordination pattern of facial, oral, and tongue musculature.*

Thus severe deformities of the dentoalveolar region occur with both macroglossia and hypoglossia.

The configuration of the lips as well as their competence and function are of great importance if the orofacial system is to develop optimally. Certain types of lip configuration which occur several times within one family may be hereditary and thus predisposing its members to dysfunction and malocclusion (Fig. 136). It is often difficult to decide whether tongue and lip habits are due to hereditary factors or due to imitation.

Rare pathological muscular conditions, such as hypertrophy and atrophy, can also cause malocclusions.

136 Genuine Class II malocclusion in three brothers

Top row: Profile views
Bottom row: Overjet

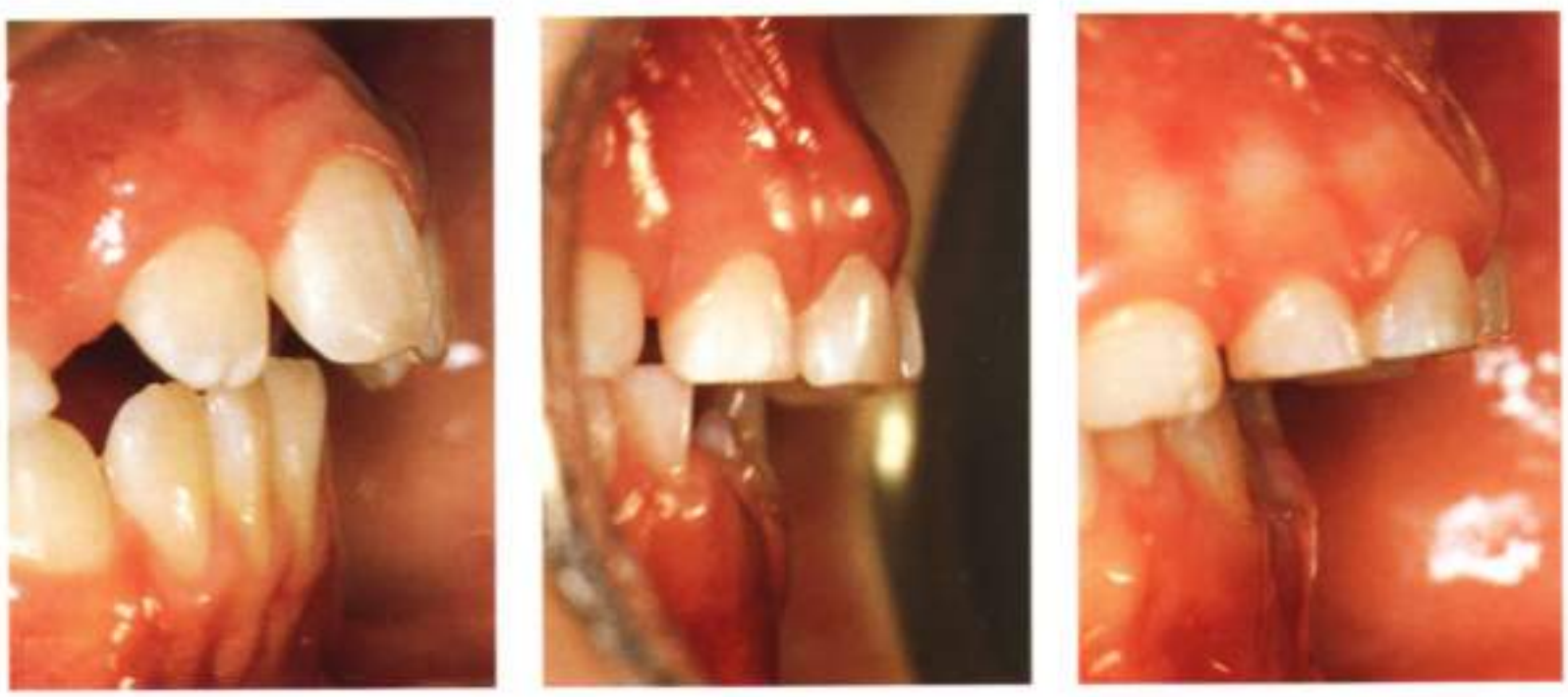
Top row: Whereas the oldest brother *(left)* has normal, competent lips, the younger siblings show a disturbed lip seal (open mouth posture, short, hypotonic upper lip).

The youngest child *(right)* has in addition a hyperfunctioning mentalis muscle.

Bottom row: Clinical pictures of the corresponding overjets.

The different degrees of the malocclusion correlate to the different amount of neuromuscular disturbance.

The oldest brother *(left)*, with normal lips, has the smallest overjet and the youngest brother, with incompetent lips and hyperactivity of the mentalis muscle, has the largest overjet *(right)*.



Dentition

As has been shown by twin studies, very many features of the dentition are hereditary:

- Size of the teeth
- Shape of the teeth
- Number of teeth
- Mineralization of teeth
- Path of eruption and primary position of tooth germ
- Sequence of eruption

Severe deviations in *shape* and *size* of the teeth are the most common causes in the genesis of dentofacial malocclusions. From the orthodontic point of view, it is usually not the actual size of the teeth which is relevant (Figs. 137, 138), but rather the size of the teeth in comparison to that of their bony bases (Figs. 139, 140).

The prevalence of *hypodontia* – without taking the third molars into consideration – was quoted by Dolder (1934) as being 3.4 %; the anomaly being less frequent in the deciduous dentition than in the permanent dentition. The third molars are the most often missing tooth, followed in descending order by the lower second premolars, the upper lateral incisors, the upper second premolars, the lower central incisors, and the upper and lower first premolars. Hypodontia often occurs in combination with other syndromes (e.g. ectodermal dysplasia, cleft of lip, jaw and palate, Down's syndrome) (Fig. 141).

The data on prevalence of *hyperodontia* show a wider range. Cases of hyperodontia are less common than cases with congenitally missing teeth. All types of tooth can be supernumerary, particularly in the permanent dentition. Hyperactivity of the dental lamina occurs more often in the upper jaw, especially in the anterior and molar regions. The next most affected teeth are the lower premolars and incisors (Fig. 151). The supernumerary tooth can be formed either normally or atypically. It can also be formed in such a manner that, due to gemination and fusion, the supernumerary structure does not develop separately but rather results in an oversized tooth (Fig. 156).

Supernumerary teeth are common in patients with cleft lip and palate around the cleft area (supernumerary lateral incisors) and in cases of cleidocranial dysostosis (Fig. 154).

137 Microdontia
Microdontia of the maxillary latera incisors.

Of all the types of teeth, the upper lateral incisors vary most in shape

Anomalies in tooth size can be restricted to individual teeth or may occur generally.

138 Macrodontia of individual teeth
Tooth anomaly in the upper anterior region due to oversized latera incisors.

139 Macrodontia of the upper teeth in relation to the size of basal bone

Due to the disproportion in size between the two structures, the anterior teeth are crowded and the posterior teeth are severely tipped buccally.

140 Microdontia of the entire dentition in relation to the size of the basal bones

The spaces between the teeth are the result of a size discrepancy between the dental arches and the basal bones.

Hypodontia

141 Hypodontia of deciduous teeth

Congenitally missing upper lateral deciduous incisors in a case with familial predisposition to hypodontia.

Right: Corresponding panoramic radiograph.

Hypodontia is rare among primary teeth.

142 Hypodontia of permanent teeth

Occlusion of the patient shown in Fig. 141 at 11 years of age. The upper lateral permanent incisors are missing.

The upper canines have erupted mesially.

In Caucasian populations, the most common teeth of the permanent dentition to be affected by congenital absence are the lower second premolars and the upper lateral incisors.

143 Position of the deciduous tooth in case of congenitally missing permanent tooth
Submerging of persistent lower, second deciduous molars – a microsymptom of congenital absence of the mandibular second premolars.

Hypodontia and occlusal relations

144 Shape of the upper dental arch
The anterior arch of this 12-year-old female patient has been flattened noticeably due to congenitally missing upper lateral incisors.

145 Occlusal findings
The discrepancy in anterior tooth size between the upper and lower arch promoted the development of an anterior cross-bite.

146 Oligodontia
Hypodontia of a large number of teeth in a patient with a bilateral cleft of lip, jaw, and palate.

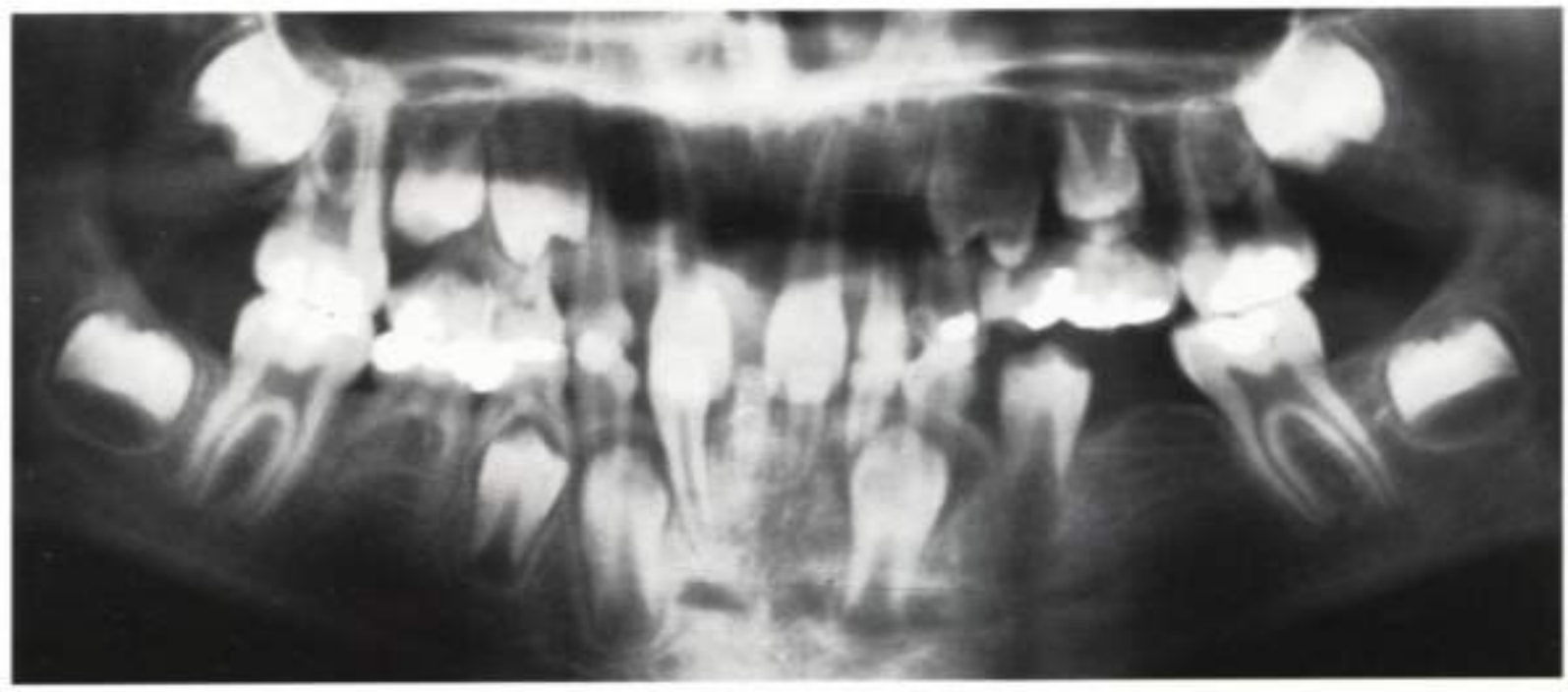
The patient shows congenital absence of the upper lateral incisors, the upper first and second premolars, the lower left central incisor, and the lower second premolars. The tooth germs of the upper permanent canines are dystopic.

Left: The oligodontia in the maxillary arch further impedes its development.

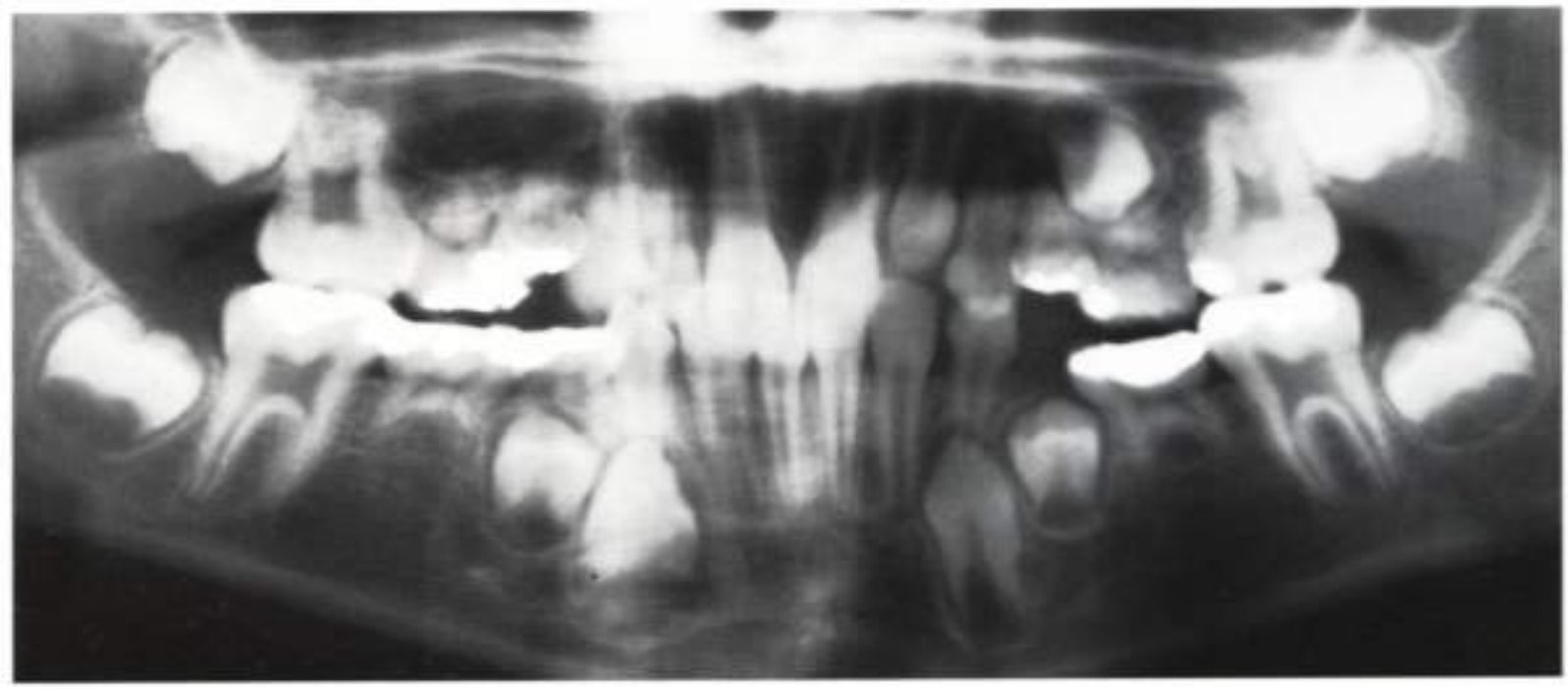
Inherited oligodontia of varying expression in four siblings

147 Teeth present in the oldest brother
Hypodontia of the upper canines, the lower second molars, and the wisdom teeth at the age of 13.5 years. The upper right deciduous canine is persistent.

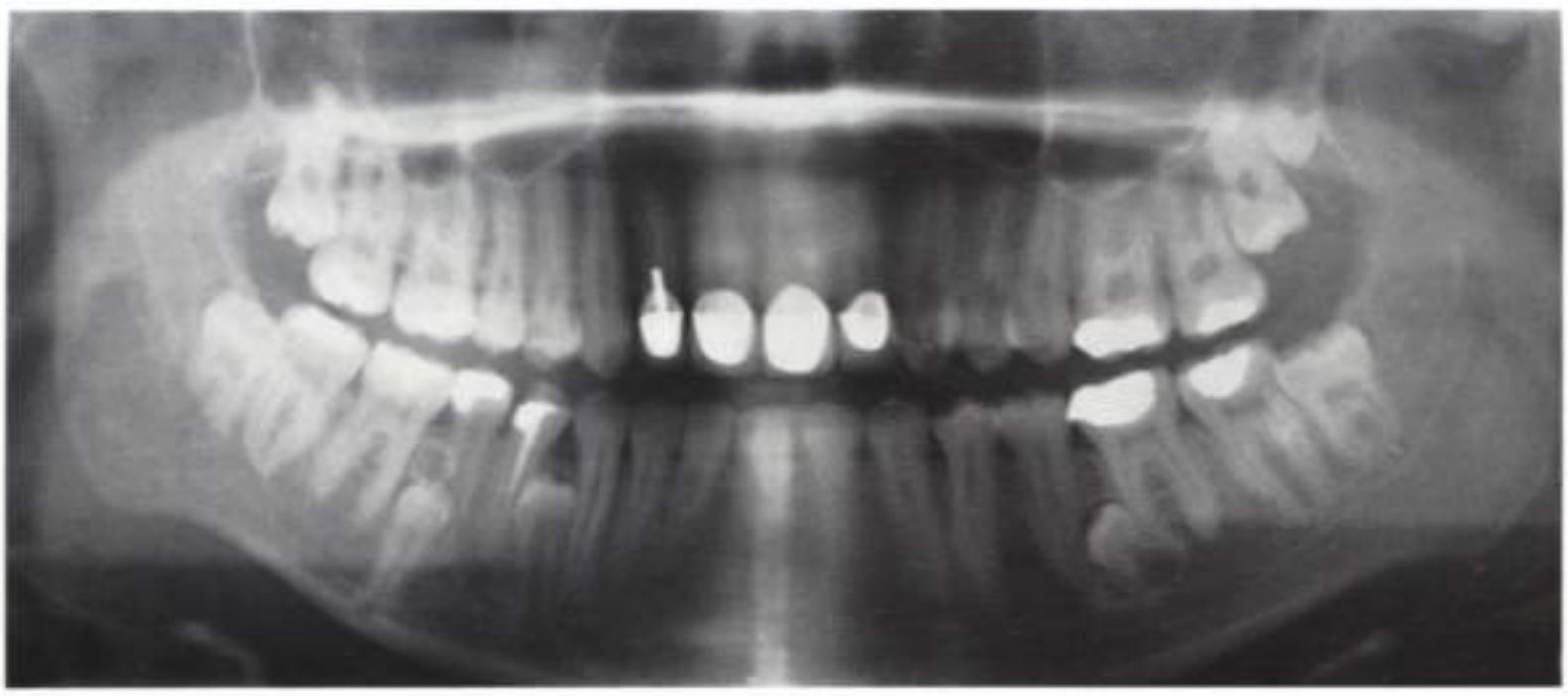
148 Teeth present in the second oldest brother
Congenital absence of the upper canines, the upper right lateral incisor, and the lower second premolars at the age of 9.5 years. The upper left lateral incisor is hypoplastic.



149 Teeth present in the youngest brother
The third son of the family has severe oligodontia at the age of 10 years – congenital absence of the upper right lateral incisor, the upper right first premolar, both upper canines and second premolars, and lower second premolars.



150 Teeth present in the sister
The youngest child of the family, a 6-year-old girl, has hypodontia of the upper right lateral incisor, the upper left second premolar and both lower second premolars. The germ of the upper left lateral incisor is hypoplastic. The germ of the upper right permanent canine is in ectopic position.



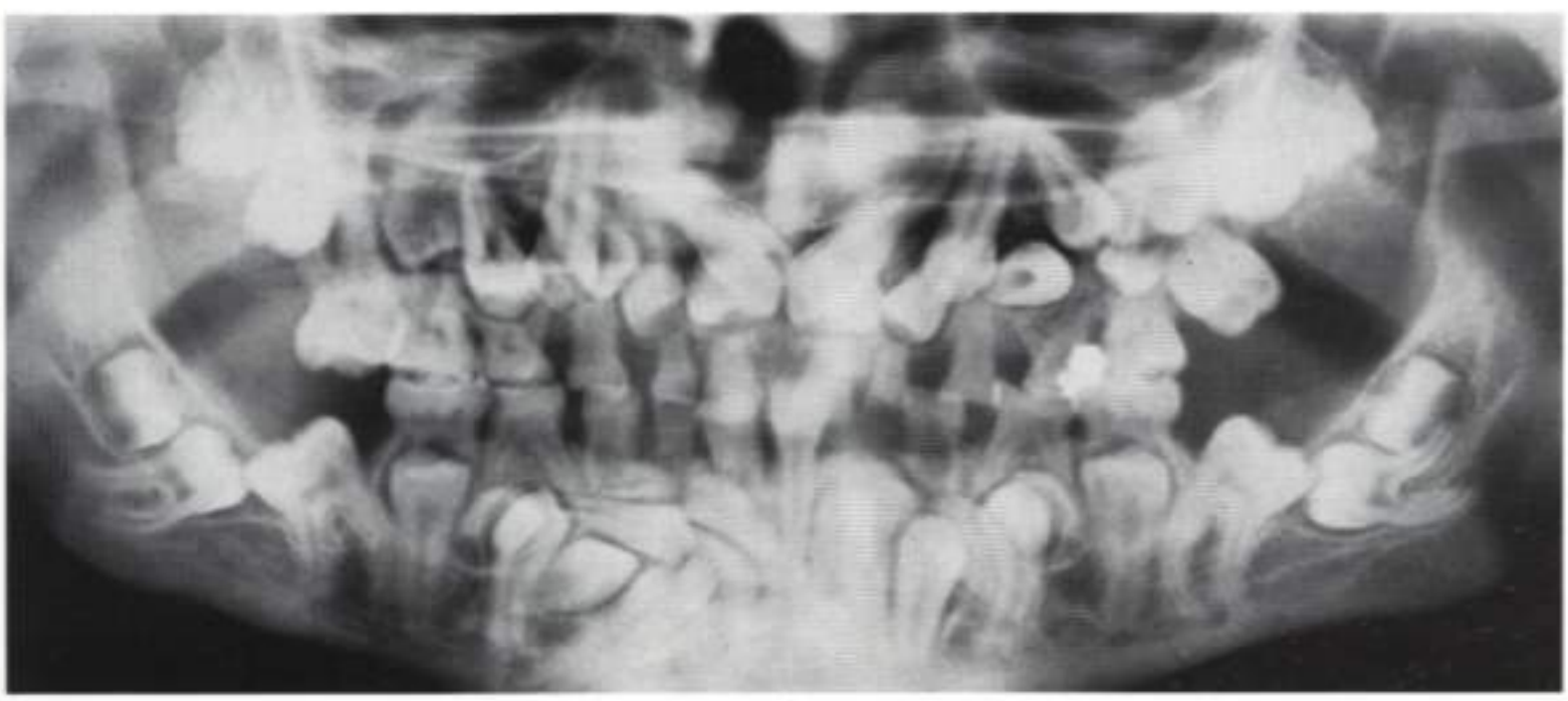
151 Hyperodontia
Radiograph of a 22-year-old female patient with four supernumerary teeth.

Supernumerary teeth are present in both premolar regions of the lower arch. The germ of a distomolar is apparent in the upper left quadrant. It is considered to be the result of excessive formation of the dental lamina.

152 Mesiodens
Supernumerary, rudimentary tooth, which has erupted between the upper central incisors.

This type of abnormality is often inherited and is the most common type of hyperodontia. It can severely impede the eruption of the anterior teeth.

153 Odontoma
Supernumerary mineralized structure located near the crown of the upper right canine which interferes with eruption of the canine and, together with the pericoronal cyst, is retaining it.



154 Hyperodontia in cleidocranial dysostosis
Multiple, ectopic, fully or partially impacted permanent teeth in a 16-year-old female patient.

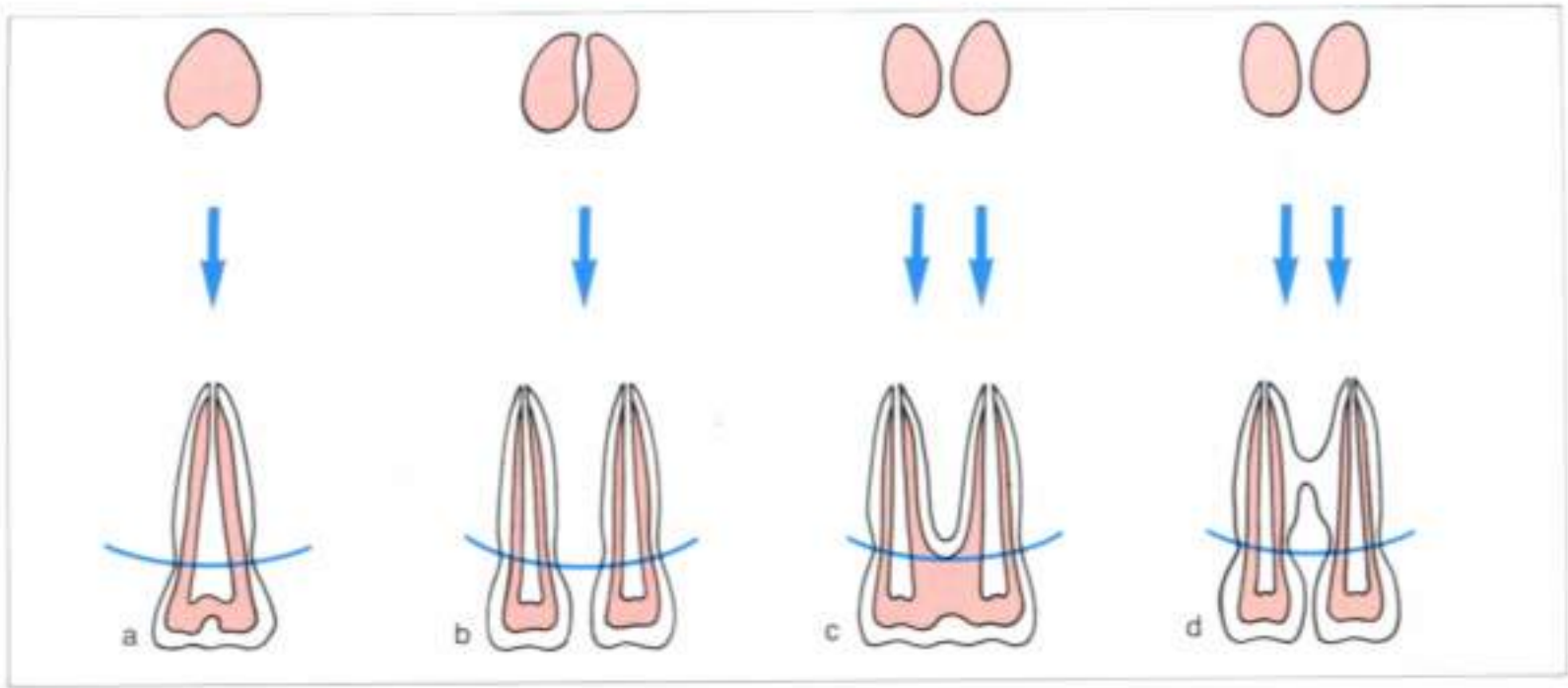
The supernumerary incisors, canines, and premolars as well as the persistence of the deciduous dentition are typical findings in this type of skeletal defect.

155 Diagrammatic view of abnormalities of tooth morphology
a Gemination = Incomplete division of one single tooth bud.

b Twinning = Complete division of one tooth bud to create 2 teeth.

c Fusion = Union of the dentin of two teeth, from two tooth buds.

d Concrescence = Union of the cellular cementum of two teeth, from two tooth buds, (*Tannenbaum* and *Alling*, 1963).



156 Gemination
Incomplete division of the tooth buds of the upper central incisors. These oversized, cosmetically unpleasant teeth are typical of this type of anomaly.

Right: The notch in the incisal edge, and the axial groove through the crown, is a result of incomplete separation of the tooth bud.

157 Twinning
Supernumerary tooth in the lower anterior region.

Judging by the shape and size of the teeth, the hyperodontia appears to be a result of the bud of the right central incisor dividing and forming two completely separate twin teeth.

158 Fusion
Fusion between an upper left central incisor and a supernumerary tooth.

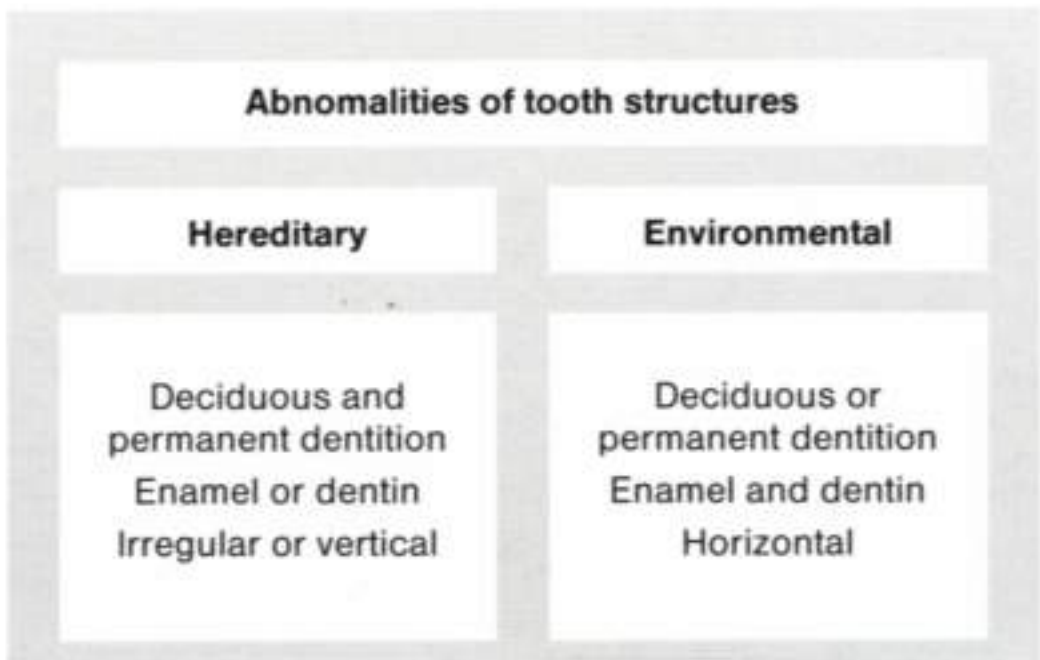
Right: The tooth crowns are partially fused. In this case, the union can be separated and the supernumerary tooth extracted.

Inherited defects of the *tooth structure* differ from exogenic-induced disturbances in mineralization as follows (Fig. 159):

1) An inherited malformation is present in both the deciduous and permanent dentition.
2) It is localized in either the enamel or the dentin.
3) Inherited defects of the tooth structure are arranged either irregularly or as vertical ridges and grooves (Fig. 162).

Dysplasias of the enamel can be either hypoplastic or aplastic (Fig. 162). Dentinogenesis imperfecta often occurs together with obliterated pulp chambers, tooth root deformities, and osteogenesis imperfecta (Figs. 160, 161).

The fact that retained teeth and ectopic teeth tend to occur frequently in the same families indicates that these abnormalities are determined genetically (Figs. 166–169).

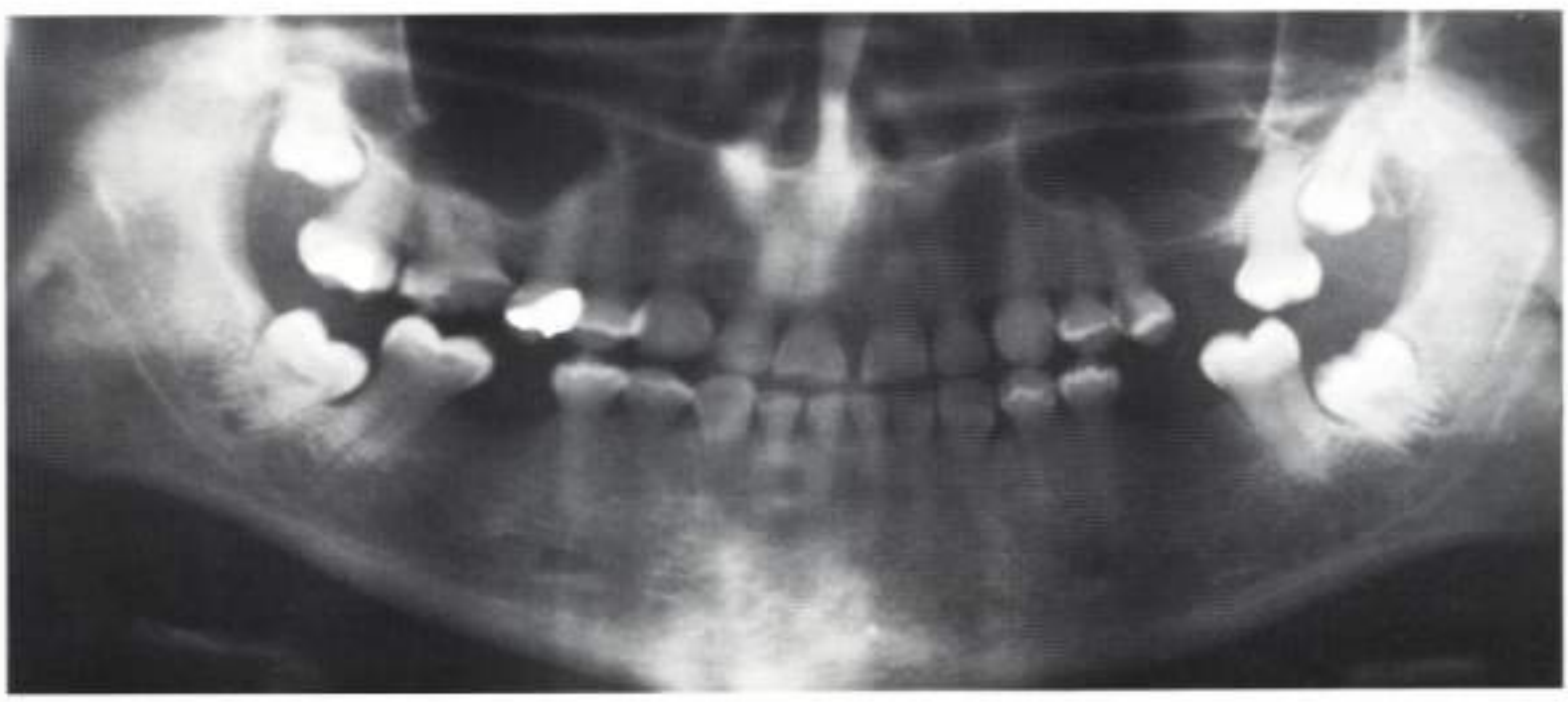


159 Disturbances in calcification due to hereditary and environmental factors
Comparison of the different pathologic symptoms of tooth structure.

Dentinogenesis imperfecta

160 Clinical findings
Hereditary dysplasia of the dentin in a 19-year-old patient.

Short, amber-colored upper and lower anterior teeth, with splintered enamel and marked attrition of the incisal edges are typical clinical findings in this disturbance in tooth formation.



161 Radiographic findings
In cases of dentinogenesis imperfecta, the radiographs reveal the following findings:

Reduced radiographic contrast of the dentin, obliteration of the pulp chambers and root canals, short, dilated roots.

Anomalies in the shape of the roots are also present with constriction in the cervical regions.

Radiograph of the patient shown in Fig. 160.

162 Amelogenesis imperfecta – Hypoplastic type

The thin, chalky – white and brown enamel is hard and its surface is rough, covered with pits and fissures. Attrition occurs at a higher rate than normal and parts of the enamel have chipped from the underlying dentin.

163 Amelogenesis imperfecta – Hypomineralized type

This 12-year-old girl has yellowish-brown, very soft enamel. The surfaces of the teeth are dull and covered with ridges and grooves. Noticeable amounts of enamel have fractured away.

The enamel dysplasia is combined with an open bite.

Amelogenesis imperfecta – Hypermature type

164 Mixed dentition

The permanent teeth have opaque white, dull enamel, and the enamel of the incisors shows the first signs of splintering. The patient is a 9-year-old boy.

The disturbance in enamel formation occurs together with a complex open bite.

165 Early stage of permanent dentition

The enamel on the canines, premolars, and molars has been dissolved and the dentin has been stained dark brown. The crowns of the teeth exhibit anomalies in shape and size.

Right: The surface of the tooth is smooth.

Occlusal findings of the patient shown in Fig. 164, at 13 years of age.

Impaction of teeth

166 Impacted second deciduous molar

Impaction of the lower right primary second molar in a 9-year-old male patient.

The space for the unerupted deciduous tooth is resticted due to mesial tipping of the adjacent tooth on the distal side, which is typical for cases of ankylosis. The permanent tooth germ has been displaced distally by the impacted deciduous tooth.

In this case the eruption abnormality is hereditary (refer to Fig. 167).

167 Hereditary impaction of deciduous teeth

Radiograph of the 7-year-old brother of the patient shown in Fig. 166. This patient shows ankylosis of the lower left deciduous second molar. The underlying germ of the permanent tooth has been displaced mesially.

The space for the unerupted tooth has been narrowed due to mesial tipping of the first permanent molar.

The eruption of the upper left deciduous second molar is also being disrupted by the same phenomenon.

168 Transposition of teeth

Two adjacent teeth have exchanged positions in the dental arch for genetic reasons.

Unilateral transposition of the left upper canine and first premolar, with congenital absence of the upper lateral incisors.

Left: Occlusal relation of the left anterior region with the malpositioned upper teeth.

Transposition of the upper canine and the premolars is the most common type observed.

169 Bilateral transposition

Both upper canines and first premolars are transposed.

The malalignment in this female patient is due to hereditary factors.

Bones

Certain genetic factors influence bone development of the mandible, the maxilla, and the other bones in the craniofacial complex, leading to hereditary osseous dysplasia. The following may be affected by these aberrations:

- Bone size
- Shape of the bones and the jaw bases
- Bone location
- Number of bones present

Whereas *bone size* anomalies account for some of the causes of hereditary micrognathism or macrognathism (Figs. 170, 171), variations in *bone location* represent some of the causes of prognathism or retrognathism.

Hereditary variations in *jaw shape* often cause asymmetries.

Unlike agnathism, which is very uncommon, *hypoplasia* and partial aplasia of the jaw bones occur together with craniofacial dysostoses, such as hereditary malformations of the area around the first branchial arch (mandibulofacial dysostosis, maxillofacial dysostosis), cleidocranial dysostosis, and Crouzon's disease (Fig. 171).

170 Hypoplasia of the mandible, combined with embryopathy
Facial profile and anteroposterior jaw relationships in a 3-year-old patient with dysmelia and various organic defects. The hypoplasia of the mandible has resulted in a receding facial profile. The malformed external ear is also apparent on the facial view. Due to severe retrognathism of the mandible, the lower lip is positioned behind the upper incisors.

Right: This type of soft-tissue morphology causes progressive increase in overjet.

171 Hypoplasia of the maxilla in Crouzon's disease (craniofacial dysostosis)
The characteristic extraoral symptoms of Crouzon's disease in this 6-year-old patient are the exophthalmos, hypertelorism, the broad root of the nose, and the protruding lower lip.

Right: Due to premature ossification of the cranial sutures, this syndrome causes congenital oxycephaly, with prominent digital cranial markings, malformations of the bony orbits, and hypoplasia of the maxilla.

The maxillary deficiency causes a skeletal Class III relationship.

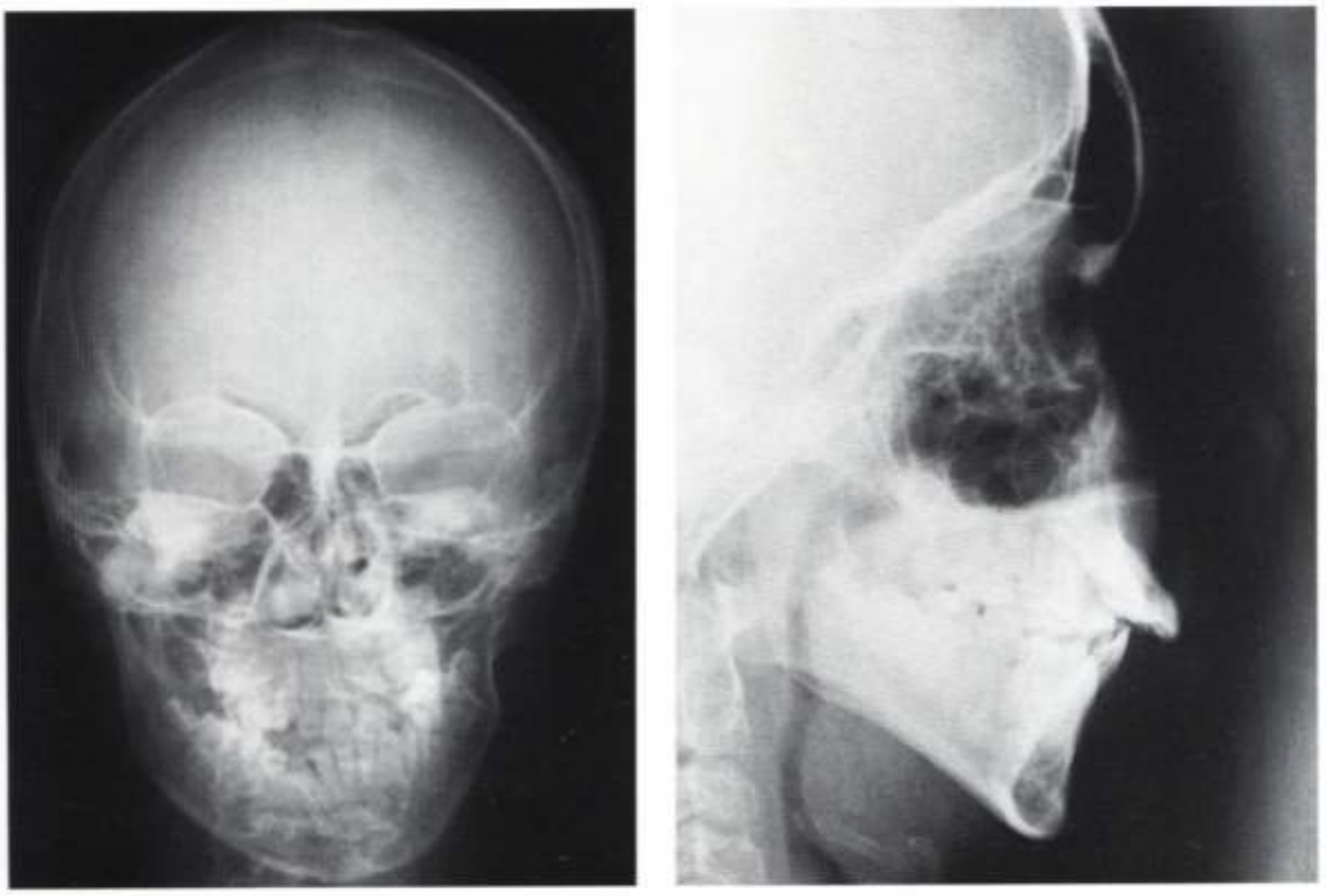
Deformities of the face and jaws caused by embryonic malformation of the second branchial arch

172 Frontal and profile views
This 13-year-old patient has hypoplasia of the right mandibular ramus. The angle of the mouth and the bony chin are distorted toward the site of malformation.

Right: The right ear is also affected by the deformity. The right auditory canal is blocked and the maldevelopment of the external ear resulted in the formation of auricular tags.

173 Radiographic findings in the panoramic view
The right ramus is almost completely missing. Whereas the right condyloid process is vestigial, the coronoid process is well developed.

The right corpus of the mandible, its gonial angle and the right half of the maxilla are underdeveloped. All tooth germs are present in both arches.



174 Radiographic findings in the posteroanterior and lateral cephalogram
The vertical development of the right half of the face has been impeded, the occlusal plane distorted upwards to the right, and the mandible, due to its hypoplasia, is shifted to the right toward the site of malformation.

Right: The maldevelopment of the lower jaw is associated with mandibular retrognathism.

Skeletal Malocclusion

Genetics play an important role in the etiology of most skeletal malocclusions. Although previously, mandibular prognathism and Class II, Division 2 malocclusions were attributed to dominant inheritance, the data derived from family and twin studies have revealed that hereditary malocclusions are nearly always transmitted as polygenic traits (Schulze, 1982), i.e. the individual deformities only develop due to the accumulative effect of several hereditary factors ("additive polygenesis"). The variability in the expression of a malocclusion in one family is due to the different numbers of genes involved (intensity) and due to the environmental factors. The exogenic influences may compensate or enhance the appearance of the malocclusion. The genetically determined traits often only become apparent in the phenotype due to the effect of environmental factors.

According to current understanding, the following *skeletal malocclusions* are hereditary: *Class II, Division 2, mandibular prognathism, bimaxillary protrusion, skeletal open bites, and skeletal mandibular retrognathism.*

Hereditary mandibular prognathism (Class III)

175 Different degrees of skeletal malocclusion in four siblings
Cephalometric lateral radiographs of the oldest *(left)* and next oldest *(right)* brother.

176 Lateral cephalograms of the two younger siblings
Left: Facial skeleton of the youngest brother.

Right: Craniofacial morphology of the youngest sister.

The degree of the anteroposterior malrelationship increases progressively from the oldest to the youngest child.

Occlusion of all four siblings prior to commencing orthodontic treatment

177 Oldest brother's occlusion
The posterior teeth have only a slight buccolingual overbite and the upper left lateral incisor and the lower canine are in edge-to-edge relation (see. Fig. 175, left).

178 Next oldest brother's occlusion
The boy shows an unilateral cross-bite on the left side associated with an anterior cross-bite of the left lateral incisors (see Fig. 175, right).

179 Youngest brother's occlusion
The patient is 7 years old and has total cross-bite (see Fig. 176, left).

180 Youngest sister's occlusion
The girl was born last and has a right lateral cross-bite in the early stage of the mixed dentition. The upper left central incisor is erupting into an anterior cross-bite relation (see Fig. 176, right).

Soft Tissues

As hereditary anomalies of the soft tissues (excluding the neuromusculature) often only have a slight effect on the genesis of orthodontic problems, they are of minor importance. The following hereditary anomalies of the soft tissues can be observed:

- Facial clefts
- Microstomia
- Anomalies of the frena
- Ankyloglossia

181 Labial frenum
Clinical picture of a high, wide frenum which is extended into the incisive papilla and occurs together with a central diastema.

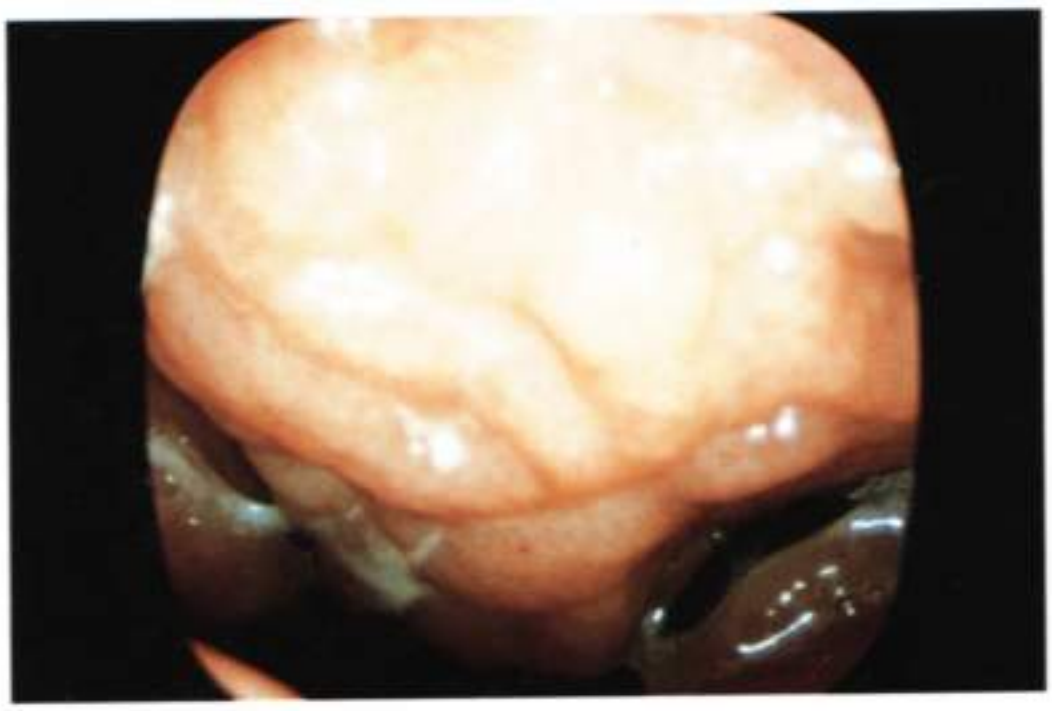
The anterior tip of the papilla is between the upper central incisors. The hereditary components of the labial frenum include the height of the point of attachment and the texture of the tissue.

Lymphatic tissue

182 Adenoids
Endoscopic picture of medium-sized adenoids.

As the size and development of lymphatic tissue may be hereditary, hyperplasia of the adenoids tends to run in families.

Right: Position of the adenoids in relation to the surrounding structures is marked on this cephalometric lateral radiograph.



183 Hyperplasia of the tonsils
Increases in the size of the tonsils, as well as of the adenoids, often run in families.

Hypertrophic lymphatic tissue in the upper respiratory tract may act as an epigenetic factor and increase the severity of a malocclusion.

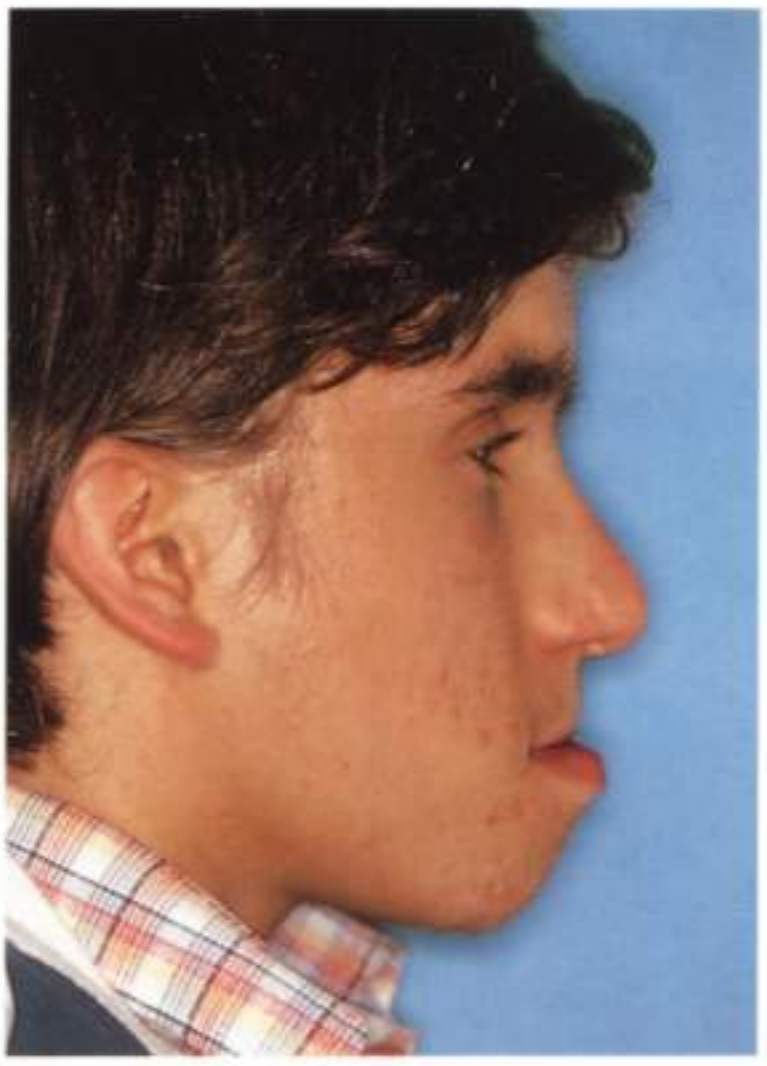
Acquired Anomalies

Developmental Damage

Those malocclusions which, etiologically speaking, were caused by developmental damage during the fetal period, are considered *congenital anomalies* (Moss, 1962, Enlow, 1982).

In many of these cases, the exact causal pathogenesis cannot be determined. The following are included among the causes of these dysplasias proven to date: (embryopathies caused by virus diseases in the mother (e.g. measles toxoplasmosis), ionizing radiation, poisonous effects (e.g. medication) or other teratogenic harmful substances. Fetal damage with this type of genesis and the following craniofacial abnormalities have been proven to be closely connected with one another: *Maldevelopment of the first and second branchial arches, micrognathism, oligodontia, and anodontia.*

The majority of cases with lip-jaw-palate clefts are included in this etiological group. Hereditary embryonal defects only account for approximately 20% of these patients (Schilli et al., 1970).



Fetal alcohol embryopathy

184 Profile and frontal view
Physiognomy of a 13-year-old patient with the extraoral symptoms characteristic of this syndrome: hypoplasia of the middle section of the face, ptosis of the eyelids and a broad nasal root. Apart from the maldevelopment of other organs, the patient's growth is also stunted. Both are typical of this syndrome.

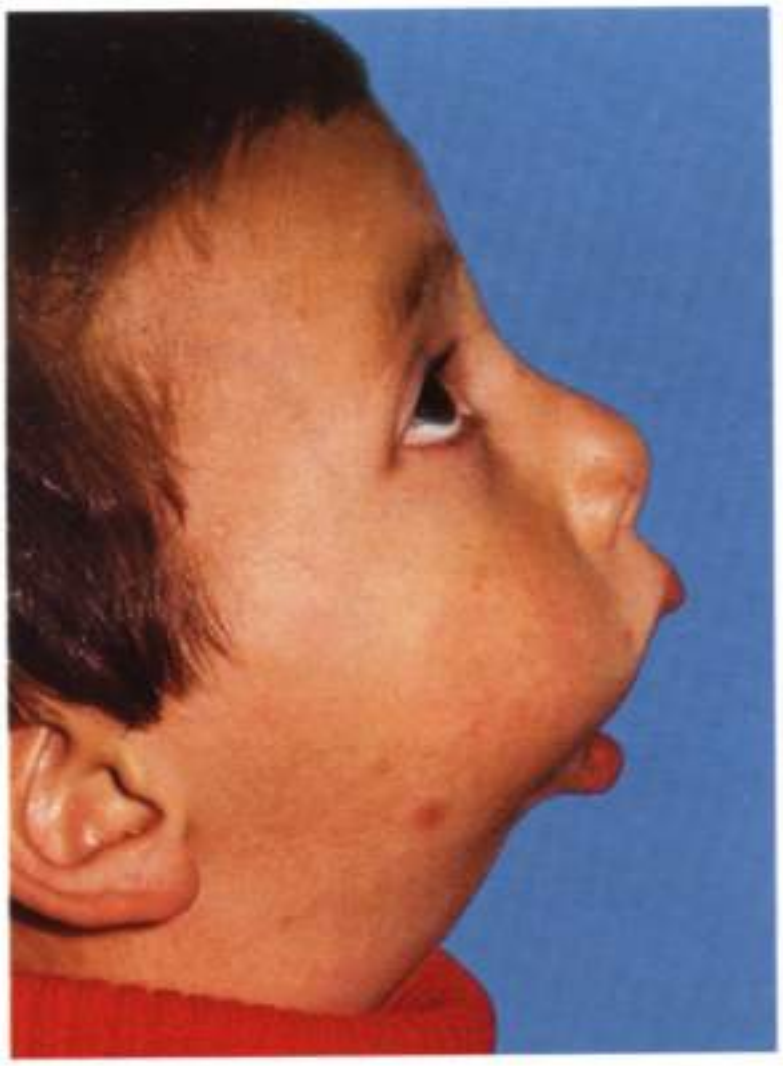
185 Craniofacial morphology in the cephalometric radiograph and occlusal relation
The hypoplasia of the middle section of the face and the resulting retruded position of the maxilla caused severe skeletal mandibular prognathism.

Left: The patient has a total crossbite.

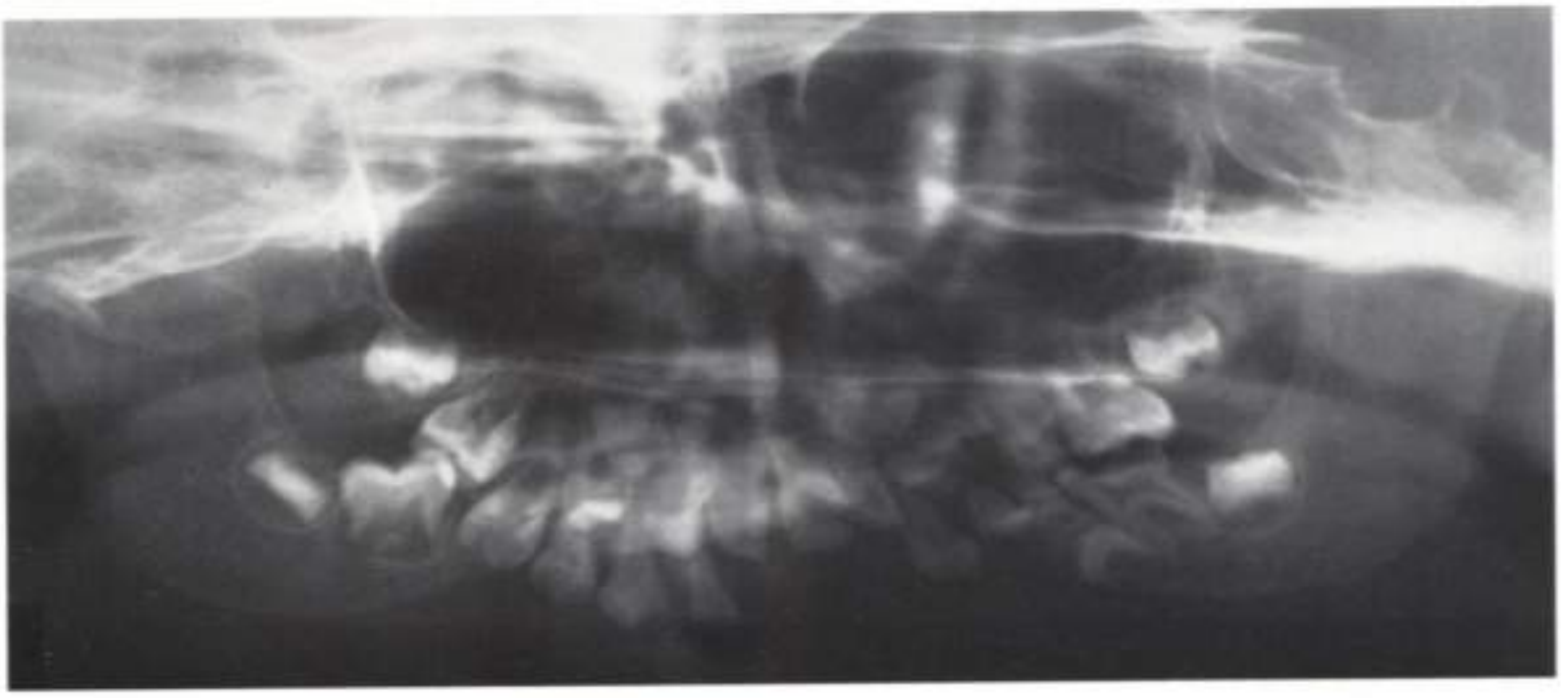
The skeletal dysplasias of this syndrome are considered to be a result of chondrogenesis being impeded by the fetal alcohol embryopathy.

Median mandibular cleft

186 Profile view and lateral cephalometric radiograph
This 6-year-old boy has hypoplasia and a severely retruded mandible with no chin, resulting from congenital mandibular dysplasia.



187 Radiographic findings in the panoramic view
Radiographic survey of the continuous clefts around the mandibular median line. Apart from the skeletal deformity, this patient suffers from agenesia of several lower anterior teeth.



188 Clinical picture of the occlusion
The soft tissues pull both segments of the mandible toward the lingual.

Right: Placing the tongue between the two segments uprights them toward the vestibule.

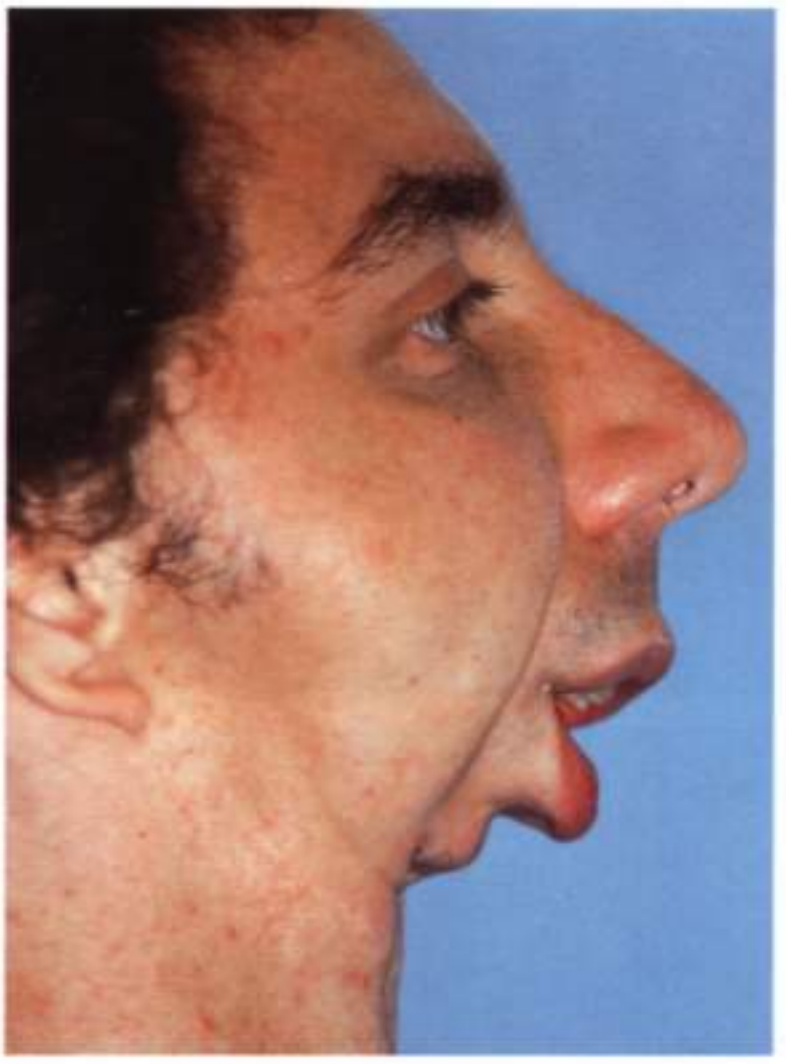
Trauma

- Prenatal trauma
- Trauma at birth
- Postnatal trauma

Prenatal intrauterine trauma can cause hypoplasia of the mandible. Should the fetus be positioned unfavorably during pregnancy, the facial skeleton very often develops asymmetrically, although this is mostly compensated for during the first few postnatal weeks.

Birth injuries are rare nowadays. Previously, forceps delivery very often harmed the areas around the TMJs, which sometimes caused ankyloses of the mandibular joints. As a result of these ankyloses during early childhood, mandibular growth was impeded severely, causing the patient to develop a "Vogelgesicht".

Postnatal trauma can occur at any age and in any area of the orofacial system. The consequences are more or less dramatic, depending on the extent and localization of the trauma and at what point in the development phase it occurs.



Ankyloses of the temporomandibular joints

189 Occlusion and profile
This 19-year-old patient has ankylosis of both TMJs due to trauma in early infancy.

Considerable inhibition of the development of the mandible occurred as a result of the early damage to the joints. The patient has an extreme case of mandibular micrognathism and the typical profile of a *"Vogelgesicht"*.

190 Frontal and lateral cephalometric radiographs
Three-dimensional view of the facial skeleton to cover the vertical and sagittal mandibular dysplasia.

Despite the ankyloses of the mandibular joints and the disturbances in mandibular growth, the intercondylar width developed properly.

191 Traumatic deformities of theeth

Left: The whitish discolored areas and notches in the labial surfaces of these lower incisors are microsymptoms of trauma experienced at 2 years of age. The horizontal shape of these decalcified zones is a typical symptom of acquired damage.

Right: The ring-shaped, yellowish/brown enamel hypoplasia on this upper lateral incisor is a result of damage by local deciduous tooth trauma while the permanent teeth were developing.

192 Dilaceration

The crown of the tooth and the hypoplastic root of this upper first molar are angled acutely. This tooth anomaly is a result of a maxillary fracture along the Le Fort I plane at 2 years of age.

Right: Radiograph of the dilacerated and displaced tooth of a female patient at 9 years of age.

193 Deformation and displacement

The clinical picture shows anomalies of shape and position of the four upper incisors, resulting from trauma to the deciduous teeth during early childhood.

Enamel formation was impeded severely on the upper central incisors resulting in gangrene. Periapical lesions have caused the formation of fistula.

194 Physical damage to teeth during development

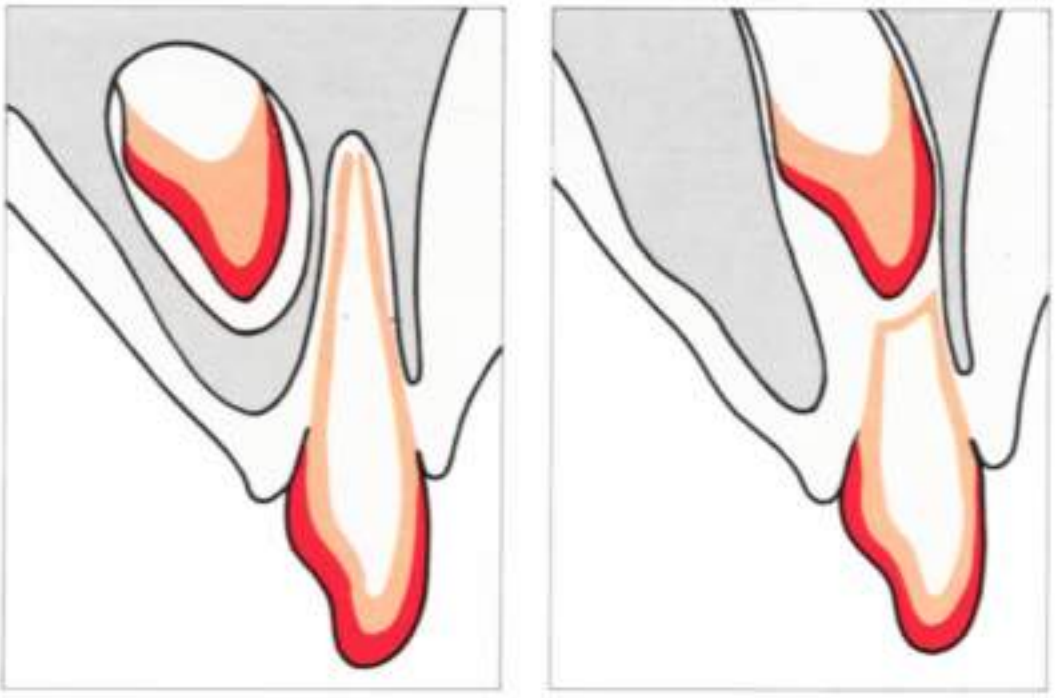
The teeth present after radiotherapy of a nasopharyngeal tumor at 3 years of age.

As a result of the radiotherapy, when the patient was 10 years old, the root formation of the permanent teeth is impeded severly. This applies particularly to the upper teeth. Further radiographic findings are: Hypoplasia of tooth germs 27, 45, 47, and aplasia of the 17, 15, and 25.

Accidents involving the dentition are differentiated according to the various sequelae:

- Injuries prior to the eruption of the deciduous teeth
- Injuries to the deciduous dentition
- Injuries to the permanent teeth after eruption

Taking the developmental periods of tooth structure into account, the type and localization of tooth maldevelopment indicate the time at which the accident occurred. Injuries to *edentulous infant jaws* lead primarily to retained teeth, displaced teeth, and malformation of the roots of deciduous teeth. Such injuries do not usually harm the germs of the permanent teeth. Not until the patient is 4 years old do traumatic *intrusions* of the deciduous anterior teeth usually harm the germs of the permanent teeth. Depending on the stage of the permanent tooth germ's development when the trauma occurs and on the direction and severity of the intrusion, the crown of the permanent tooth may be damaged to a greater or lesser degree; root formation may be impeded, tooth eruption may be disturbed and the teeth may be displaced. Injuries to the permanent maxillary anterior teeth are much more common in patients with an Angle Class II, Division 1 malocclusion.



195 Deciduous teeth trauma and damage to the germs of the permanent teeth
Sagittal section through the maxillary alveolar process.

Left: Topographic relationships of a 3-year-old. The germ of the permanent tooth is only damaged if deciduous tooth intrusion and palatal tilting of the root take place simultaneously.
Right: At 5 years of age the position of the tooth germ has changed and is endangered by any intrusion of the deciduous tooth (*Eschler*, 1974).

196 Incisor ectopy
Horizontal displacement of the right upper central incisor due to trauma of the deciduous teeth.

It is uncertain whether the tooth will become correctly aligned in the dental arch.

Right: Due to the premature loss of the upper right deciduous incisor and the germ of the permanent tooth being displaced, the adjacent teeth have drifted toward the gap and have severely restricted the space for the successional permanent tooth.

197 Deciduous tooth trauma and tooth deformities
Left: Radiograph showing traumatic intrusion of the upper central primary incisors of a 4-year-old.

Right: Radiograph of the permanent incisors 4 years later. The trauma impeded the development of the roots of both teeth.

The patient is now 8 years old and has permanent incisors with cervical root fractures as a result of another accident at that point in time.

Physical Factors

The following factors, which enhance the development of an anomaly, or directly cause it, belong to this group:

- Feeding method
- Consistency of the diet
- Premature loss of deciduous teeth
- Mouth breathing

The feeding method during infancy is considered important with regard to the etiology of a retruded mandibular position in the deciduous dentition. The main advantage, from the orthodontic point of view, of breastfeeding compared to bottle feeding is that the baby must activate and protract the jaw musculature much more to press the milk out of the mother's breast (Fig. 198). This higher functional loading during the first few months of life helps to move the mandible anteriorly and compensates for the physiologic retruded antero-posterior jaw relationship which exists at birth. Even specially shaped nursing nipples cannot fully match the advantages of breastfeeding.

The child can already chew once the first deciduous molars have erupted. It is particularly important for the development of normal dentition that the child is given solid food from this point on (Fig. 199).

Should the child be given further nonsolid foods, it will become a "temporalis chewer," i.e. it will only carry out chopping movements (Fig. 202), instead of a *"masseter chewer"* which carries out complete grinding cycles during mastication (Fig. 200). The insufficient functional loading associated with a *"temporalis chewer"* adversely affects the formation of the bone structures, thus the consistency of the foodstuff indirectly influences jaw development.

198 Feeding infants
Due to the advantages it offers regarding, among other things, the development of the dentition, breastfeeding is preferable.

Right: If the infant should be bottle-fed, the NUK nipples are considered superior to conventional nipples as their physiological shape is matched to the infant's anatomy.

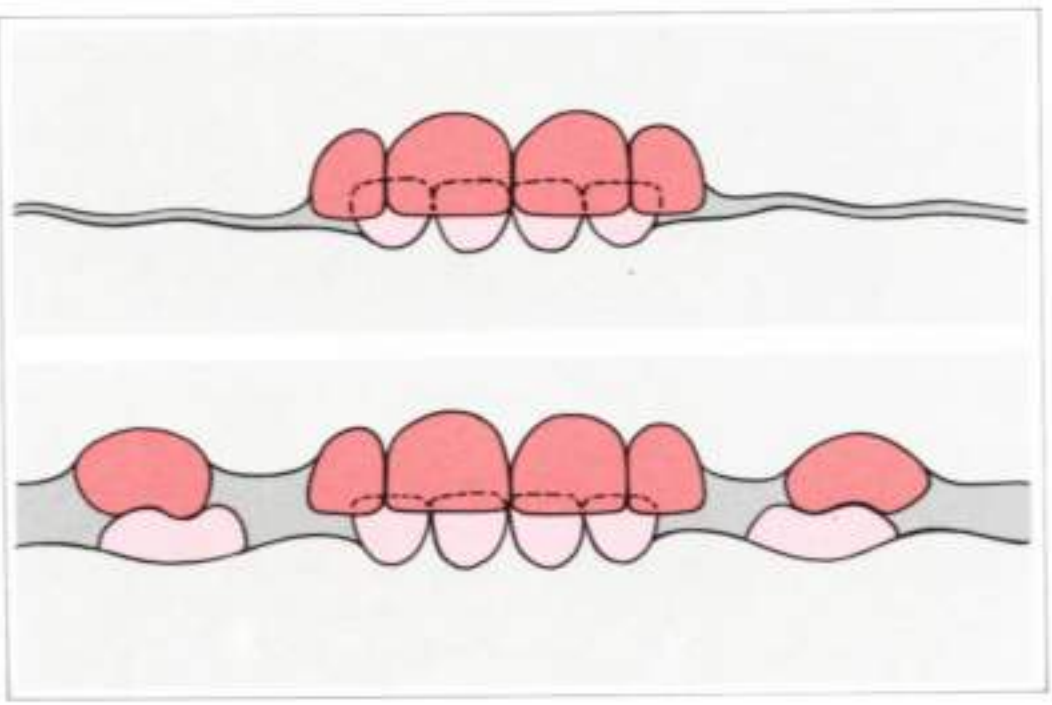
The advantages of breastfeeding compared to bottle feeding for the child

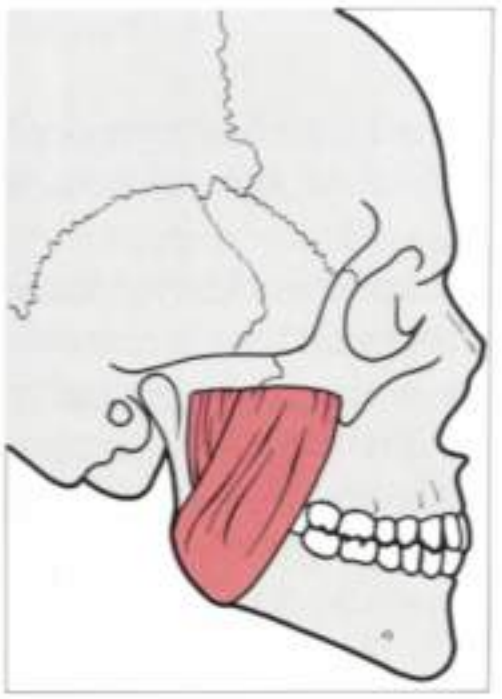
→ Reduced morbidity

→ Satisfied sucking reflex (→ fewer sucking habits)

→ Muscle activity 60 x as strong

199 Changing from liquid to solid foods
Once the first deciduous molars have erupted, i.e. at the time the bite is first raised physiologically (at approximately 14 months of age), the child should only be given solid foots in order to ensure that the deciduous dentition develops normally.
Above: Deep overbite prior to the eruption of the deciduous molars. The posterior alveolar processes are in contact with each other.
Below: The erupting first deciduous molars raise the bite and reduce the overbite.





"Masseter chewing" and development of the deciduous dentition

1) High functional load, strong bony framework
2) Food is ground up
3) Deciduous teeth are abraded
4) Lower dental arch is displaced forward
5) First molars are positioned favorably
6) Decreased overbite

200 Advantages of "masseter chewing" for the development of the deciduous dentition

Left: The masticatory movements are mainly carried out by the masseter, which exerts a protrusive force on the growing mandible, thus helping to compensate for the child's physiologically retruded mandibular position.

Right: Table showing the characteristics of a "masseter chewer."

201 Normal, mature deciduous dentition of a "massetter chewer"

Occlusion of a 5-year-old girl at the beginning of anterior exfoliation. The typical characteristics of this masticatory mode are: Physiologic formation of gaps between the anterior deciduous teeth, anterior displacement of the mandible and a slight overbite due to abrasion of the deciduous teeth.

"Temporalis chewing" and development of the deciduous dentition

1) Low functional load, incomplete development of bony framework
2) Food is chewed superficially
3) Minimal abrasion of the deciduous teeth
4) Lower dental arch is not displaced anteriorly
5) First molars are in unstable occlusal position
6) Excessive overbite

202 Drawbacks of "temporalis chewing" for the development of the deciduous dentition

Left: The temporalis carries out most of the work during masticatory excursions. It exerts tension cranially, primarily cranioposteriorly, and tends to promote the formation of a deep overbite.

This muscle does not exert a protrusive force.

Right: Table showing the characteristics of a "temporalis chewer."

203 Abnormal deciduous dentition of a "temporalis chewer" prior to anterior exfoliation

The typical symptoms of this masticatory mode are: The deep overbite impedes masticatory functioning, the deciduous teeth are not abraded and the mandible is retrognathic.

Premature Loss of Deciduous Teeth

Premature loss of the deciduous teeth also has a *physical effect* on the etiology of many abnormalities of the jaws and the dentition. The primary effect is the reduction in masticatory potential after premature loss of one or several deciduous teeth. The reduced masticatory potential leads to insufficient functional loading and can impede jaw development along the sagittal, transverse, and vertical planes.

The term "premature" applies to any loss of deciduous teeth which takes place more than 6 months prior to the expected date of eruption of the underlying permanent tooth germ.

A deciduous crown which has been destroyed can neither function as a tooth nor maintain the space for the permanent tooth germ. There is also a risk that periapical infections of carious deciduous teeth will endanger the crown formation of the succedaneous tooth germ.

Cariogenic food and premature loss of deciduous teeth

204 Upper deciduous dental arch
Premature loss of all upper deciduous crowns due to the cariogenic effect of sugar-saturated infants' tea.

205 Occlusion
Occlusal relationship of the patient shown in Fig. 204.

Since the masticatory function has been reduced, the jaws cannot be loaded sufficiently.

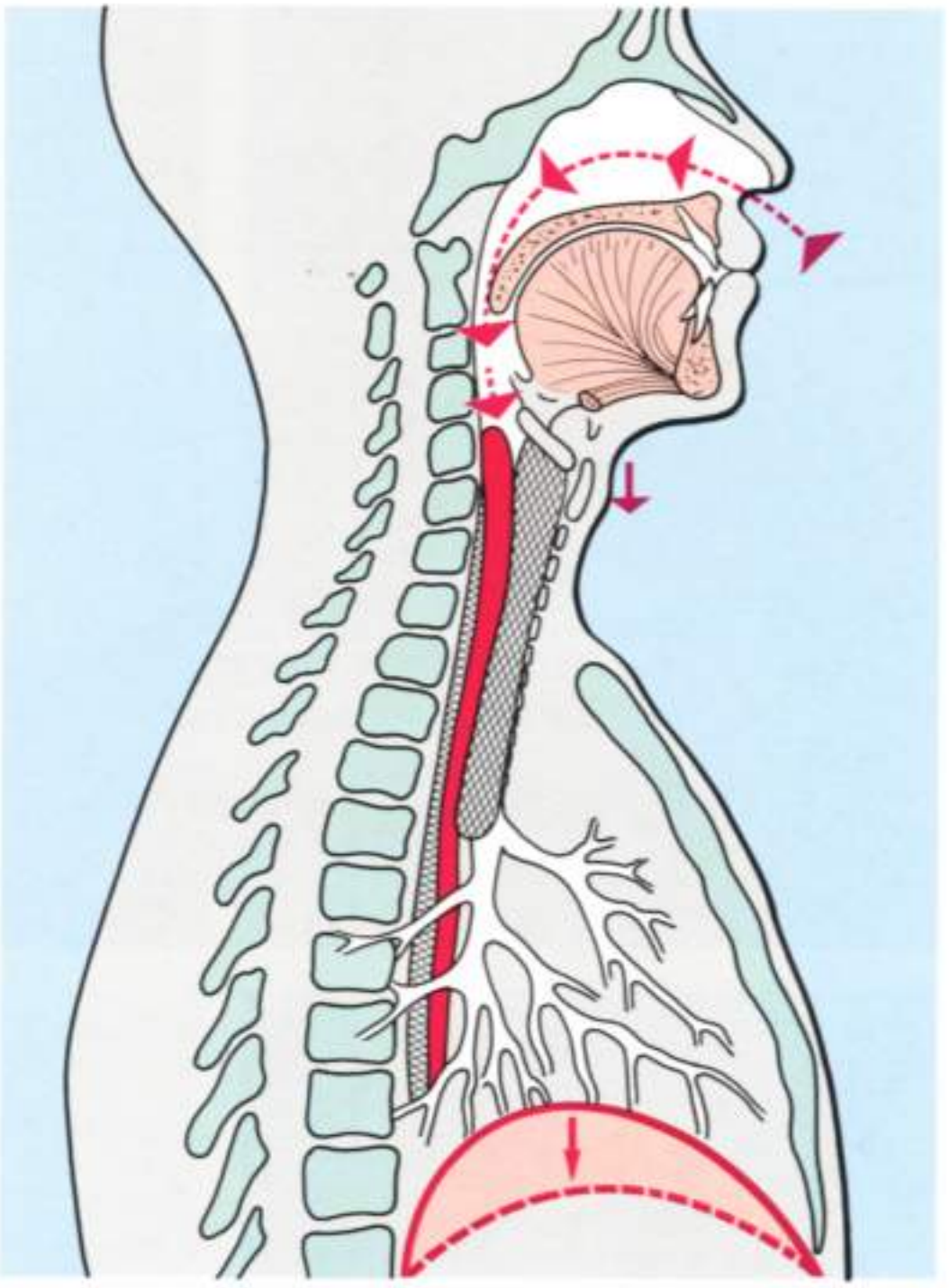
206 Deep overbite in conjunction with premature loss of deciduous teeth
A gingivally-supported, deep overbite after extensive premature loss of upper deciduous teeth over a long period of time.

The lack of tooth support has caused the mandible to rotate forward and upward, resulting in a closed bite or excessive overbite.

Breathing

In case of an impeded nasal respiration, the paranasal sinuses are not ventilated correctly and the growth-promoting effect of the capsular matrix as described by Moss (p. 33) is reduced.

Chronic disturbance in nasal breathing, or habitual mouth breathing are primarily associated with impeded maxillary growth. This maldevelopment of the maxilla results in a narrow jaw with a high palate and dental crowding as well as retrognathism or prognathism of the mandible. The lack of maxillary growth associated with oronasal respiration is due to the change in tongue position of mouth breathers. As it lies flat in the floor of the mouth it cannot play its normal role in developing the maxilla. As the tongue is displaced downward, the centrifugal and centripetal forces acting on the maxilla are no longer balanced. The functional hyperactivity of the musculature of facial expression, especially of the buccinator, impedes the development of the maxilla.

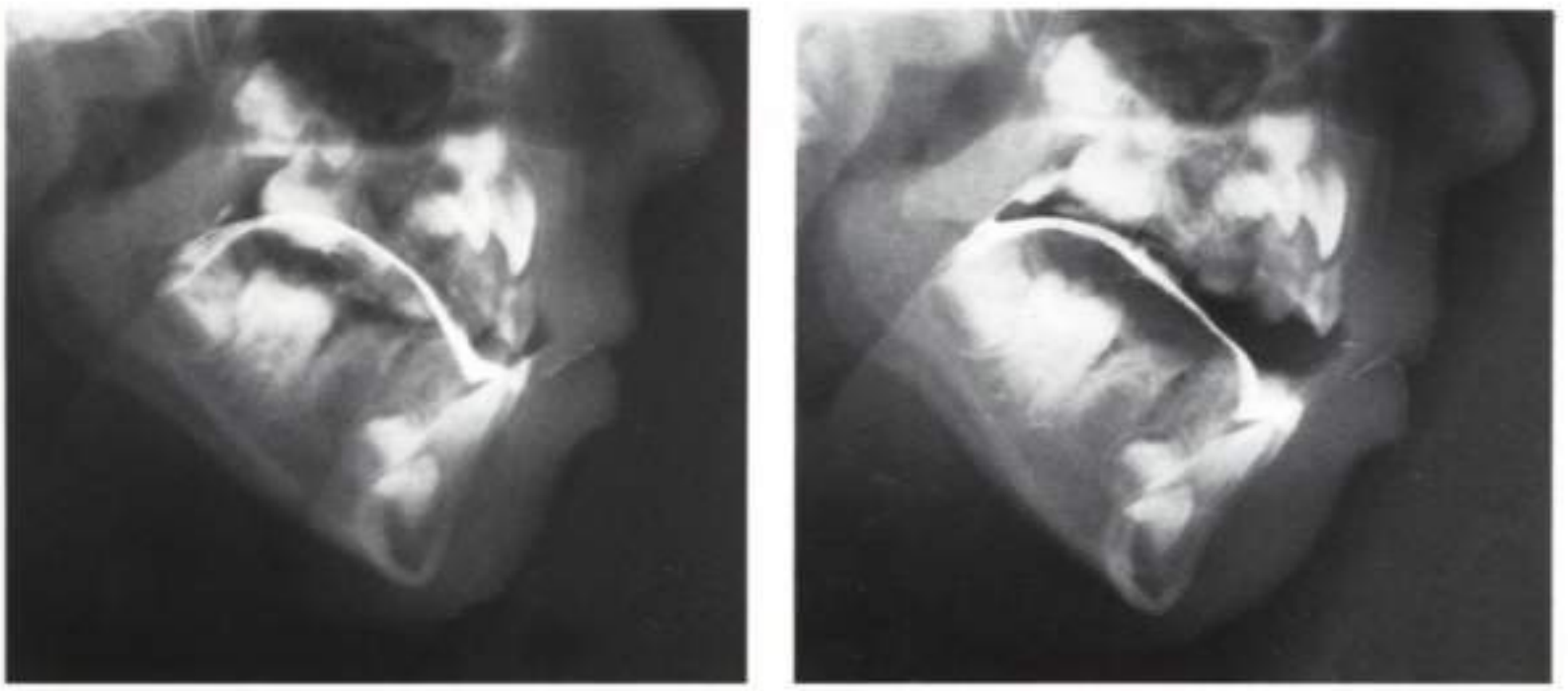


207 Pressure relationships during nasal breathing (paramedian section through the head and upper part of the body)

In order to be able to breathe normally, the nose must allow sufficient air to pass through and the oral airway must be sealed anteriorly.

While inspiring, a low pressure zone develops between the tongue and the hard palate caused by the slightly stronger traction forces opposing the air pressure. The elastic traction forces of the tracheobronchial system, which is connected to the tongue via the larynx and hyoid, are of great significance.

The drawing shows the downward displacement of the larynx and the diaphragm during inspiration, as a result of the elastic, traction forces exerted by the tracheobronchial system (after *Ekker-Möbius*, 1962).



208 Oronasal breathing in conjunction with an anterior cross-bite

Left: Occlusal relation.

Right: Habitual mandibular rest-position of a 5-year-old patient. To allow oral respiration, the tongue is kept low and the mandible is opened further downward than normal when at rest. Such changes in the balance of the orofacial and masticatory musculature adversely affect the normal development of the dentition (the dorsum of the tongue has been marked with a contrast medium).

Oronasal breathing in conjunction with a Class II malocclusion

209 Extraoral findings
Profile view of a 7-year-old patient, showing the retruded position of the lower jaw.

Right: The patient has a stenosis in the left side of the nose, which impedes normal nasal breathing.

210 Occlusion
The patient has anterior crowding in both the upper and lower jaws.

211 Craniofacial morphology and anteroposterior jaw relation
The lateral cephalogram shows the downward and retracted position of the tongue, which is typical for cases with disturbed nasal breathing and a Class II malocclusion.

Right: As the mandible is in a retruded position, the overjet is increased clinically.

Bad Habits – Orofacial Dysfunction

- Pacifier sucking
- Thumb sucking
- Finger sucking
- Tongue-thrust
- Lip sucking or biting
- Cheek sucking
- Nail biting or pencil chewing

Impeded function of the orofacial system is the most common cause of acquired anomalies. The most common bad habits are listed above.

Although the different sucking habits may produce various abnormalities, there is not always a direct causal relation.

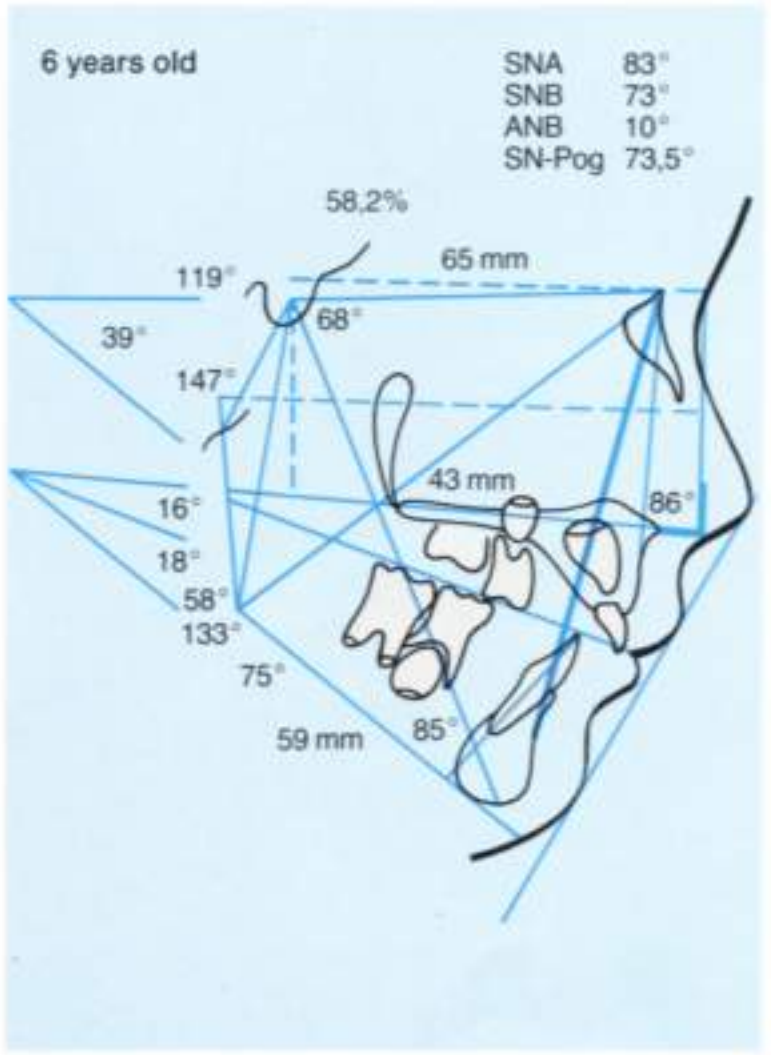
Apart from the genetic predisposition, the relationship between orofacial dysfunction and malocclusion is determined by three essential factors: The *intensity, duration,* and *type* of sucking habit.

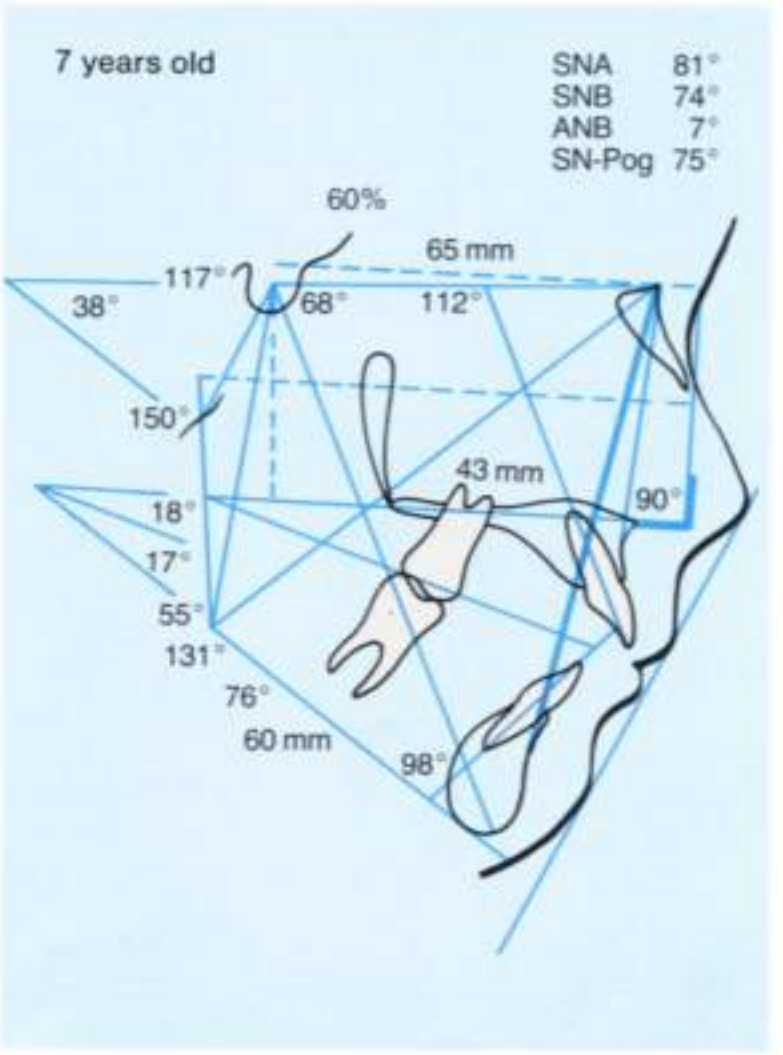
Sucking habit and malocclusion

212 Effect of the sucking habit on the dentofacial development

Left: Lateral cephalogram of a 6-year-old girl prior to acquiring a sucking habit. The girl has a skeletal Class II and is in the early mixed dentition.

Right: Configuration of the craniofacial morphology at 7 years of age. The girl began her sucking habit when she started school, which influenced the position of both the upper and lower permanent incisors during their eruption.





213 Roentgenocephalometric findings

Cephalometric tracings of the lateral headplates shown in Fig. 212.

Left: Initial situation.

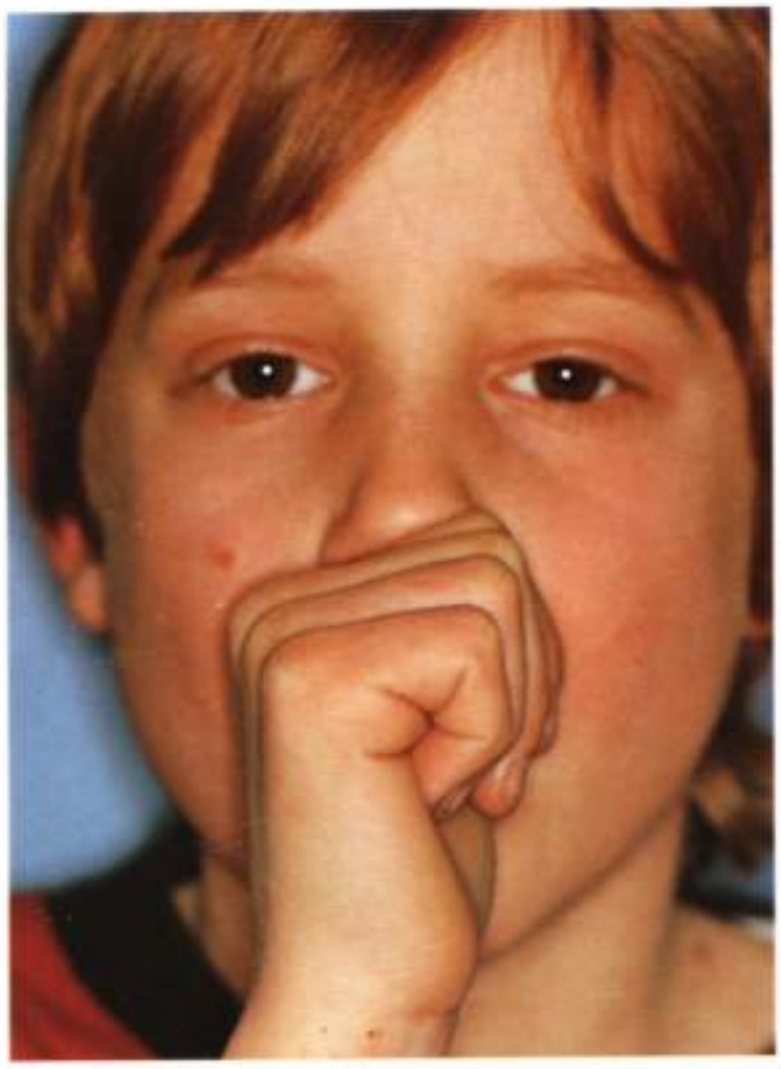
Right: Situation 1 year after commencing the sucking habit.

When compared to the initial condition, the sucking habit caused a labial tipping of the upper and lower incisors and an anterior open bite. Simultaneously, the habit promoted upward rotation of the anterior maxilla during its development (increase in the angle of inclination according to *A. M. Schwarz*).

Mechanics of sucking

214 Apposition of the sucking finger on the maxilla
Left: Sucking the right thumb, involving the nose.

Right: Thumb position depicted on a radiograph. The patient presses the thumb onto the palate, on both the front section of the maxilla and the upper anterior teeth. The finger also rests on the lower incisors as a fulcrum.



215 Intraoral symptoms
Left: Sucking or pressing the thumb against the maxilla promotes the development of a Class II malocclusion (same patient as in Fig. 214).

Right: If the finger is rested on the mandible, the lower teeth are often moved forwards resulting in an edge-to-edge bite or a cross-bite (same patient as in Fig. 216).

216 Apposition of the sucking finger on the mandible
Left: This 9-year-old female patient is demonstrating a typical finger-sucking position: The ring finger and little finger are pressed onto the lingual side of the mandibular alveolar process and the lower anterior teeth; the index and middle fingers rest on the cheek.

Right: Radiograph depicting this habit.

This type of sucking habit tilts the upper and lower teeth toward the labial. The change in position of the upper teeth is mostly mechanical and that of the lower teeth a secondary effect of the forward downward tongue posture.

Tongue-thrust can be a primary etiological cause of a malocclusion or it can be a secondary, adaptive factor, as in cases with a skeletal open bite.

In many cases, the tongue dysfunction persists once the long-term sucking habit or incorrect bottle-feeding during infancy has been discontinued (Fig. 217).

Visceral swallowing (infantile swallowing) has a time-linked etiology for tongue-thrust. It is physiologically normal until the child is 4 years old. After this time, the visceral swallowing act is considered an orofacial dysfunction. Should this type of deglutition, with tongue-thrust and contraction of the facial musculature, persist in older children and adults, it may be among others a result of a long-term sucking habit associated with an open bite (Figs. 218, 219).

217 Adaptive tongue-thrust
Anterior open bite with tongue dysfunction, caused by a long-term sucking habit.

In many cases, the tongue dyskinesia persists even after the sucking habit has been discontinued so that the malocclusion or dental malalignment cannot be restored to normal by autonomous adjustment.

Visceral swallowing

218 Tongue posture
Tongue posture typical of visceral swallowing. To initiate the swallowing act, the tip of the tongue rests on the lower lip.

219 Occlusion
Characteristic occlusion in case of persistent visceral swallowing. The tongue is placed continuously between the teeth, resulting in a complex open bite, which is only supported by the molars.

Diseases

Various general and local diseases may cause malocclusions.

The most common *systemic* diseases are endocrine disturbances (impeded increase in jaw length, disturbances in tooth eruption, reduction in tooth size) and chromosome aberrations which affect the orofacial system (e.g. *Franceschetti syndrome, cleidocranial dysostosis, trisomy 21, ectodermal dysplasia, amelogenesis and dentinogenesis imperfecta, as well as certain types of lip-jaw-palate clefts*).

The following *local* diseases very often lead to dysgnathias:

- Nasopharyngeal diseases and impeded nasal breathing
- Infections of the middle ear in babies and infants with damaged temporomandibular joints
- Gingival and periodontal diseases which may already occur in the mixed dentition
- Rare pathologic conditions (tumors and cysts)
- Caries and premature tooth extractions

Cleidocranial dysostosis

220 Craniofacial radiographic findings

This mostly dominantly inherited skeletal dysplasia results from disturbances in intramembranous ossification, whereby enchondral ossification is usually also involved.

Left: Brachycephaly and underdevelopment of the middle face with relative hyperplasia of the body of the mandible tending toward a Class III malocclusion, which is typical of this disease, are apparent on this lateral radiograph.

Right: Disturbed ossification around the calvarium, which is typical of this dysostosis, causes the fontanelles and cranial sutures to remain open for a long time.

The persisting deciduous teeth are also visible with hyperodontia and retained permanent teeth.

221 Clinical findings

Left: Hypoplasia of the collarbones and the resulting hypermobility of the shoulder joints are typical of this syndrome.

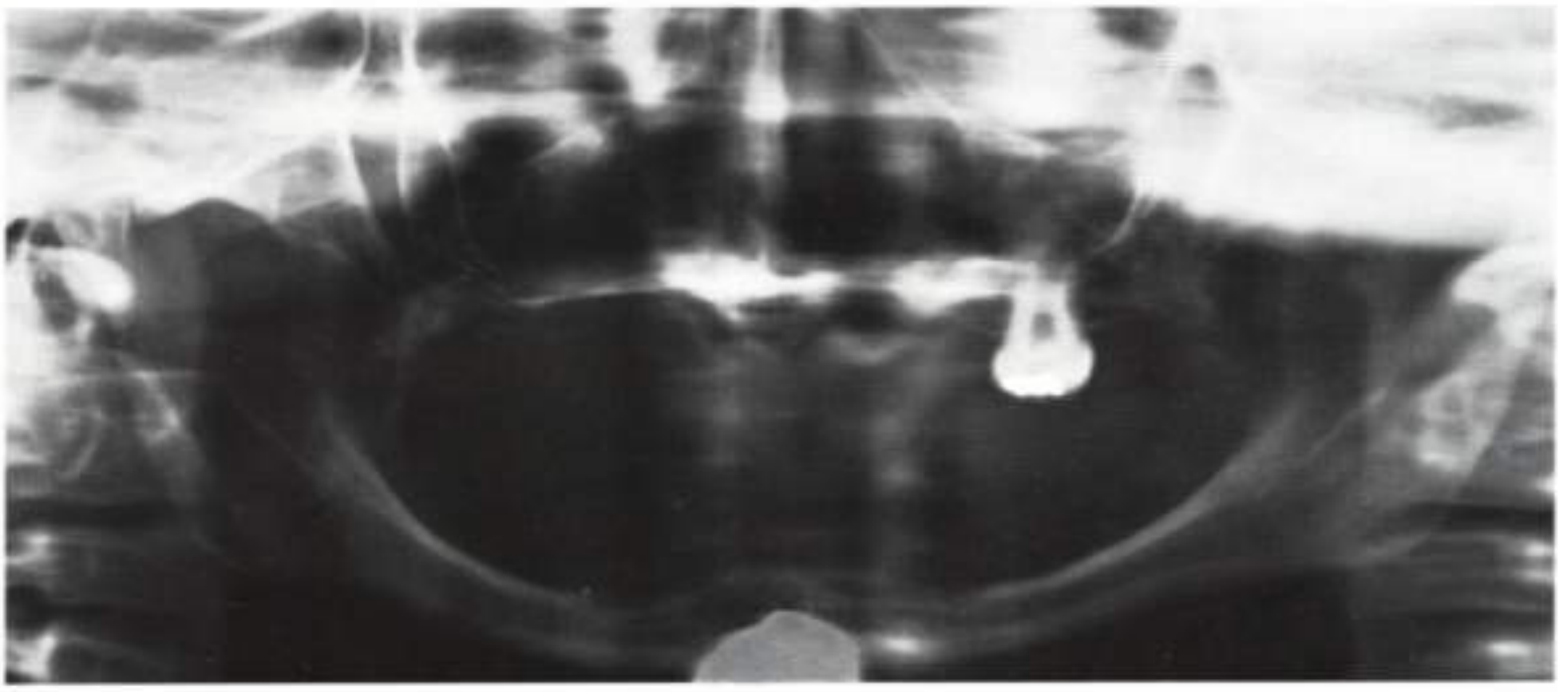
Right: The 16-year-old female patient has retained her entire deciduous dentition except for the lower central incisors. The primary incisors have been subjected to severe attrition; the deep overbite is gingivally supported.

Ectodermal dysplasia – hypohidrotic type

222 Extraoral findings of ectodermal disease
This disease is a maldevelopment syndrome of derivatives of the ectoderm.

This frontal view shows a 9-year-old female patient with the typical pathologic symptoms: Light, very thin hair, underdeveloped eyebrows, sparse eyelashes, a broad nose, ridge-like lip configuration, and pronounced mentolabial sulcus.

Left: Very dry, scaly skin with chronic eczema is typical of this disease.



223 Panoramic radiograph
Complete anodontia of the mandible. The only permanent tooth which has developed is the upper left molar. The only teeth of the primary dentition, i.e. the two upper second deciduous molars, were lost prematurely due to caries.

224 Skeletal and soft-tissue facial profile
Lateral cephalogram and profile facial view of the patient show the underdevelopment of the middle face and lower facial height.

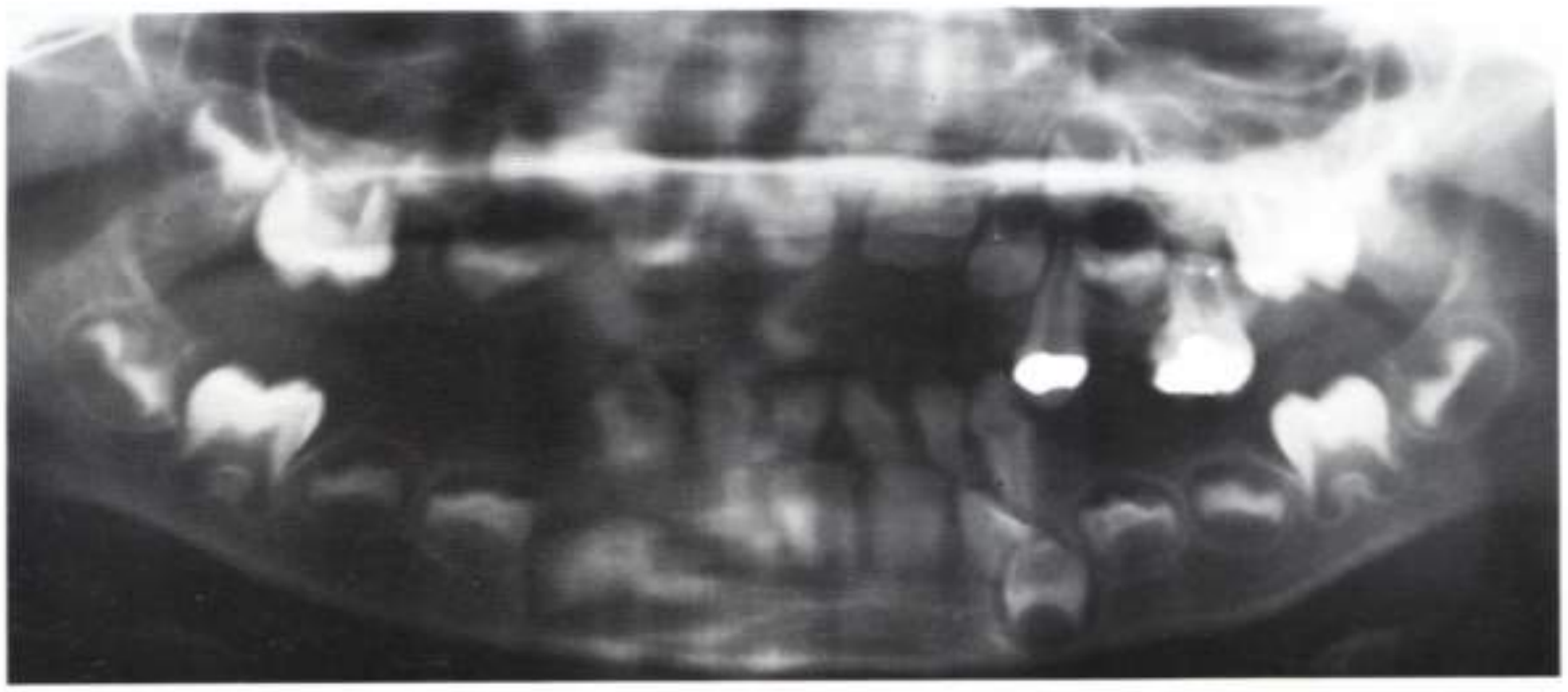
The hypoplasia of the alveolar processes results from the virtually complete anodontia.

Left: Disturbances in the development of the teeth and skeleton have produced characteristic changes in the soft-tissue profile.

Cysts and tooth eruption
– Case example –

225 Initial situation
Panoramic radiograph of a 4-year-old female patient who was sent for treatment of an abscess which resulted from carious anterior deciduous teeth in the lower arch.

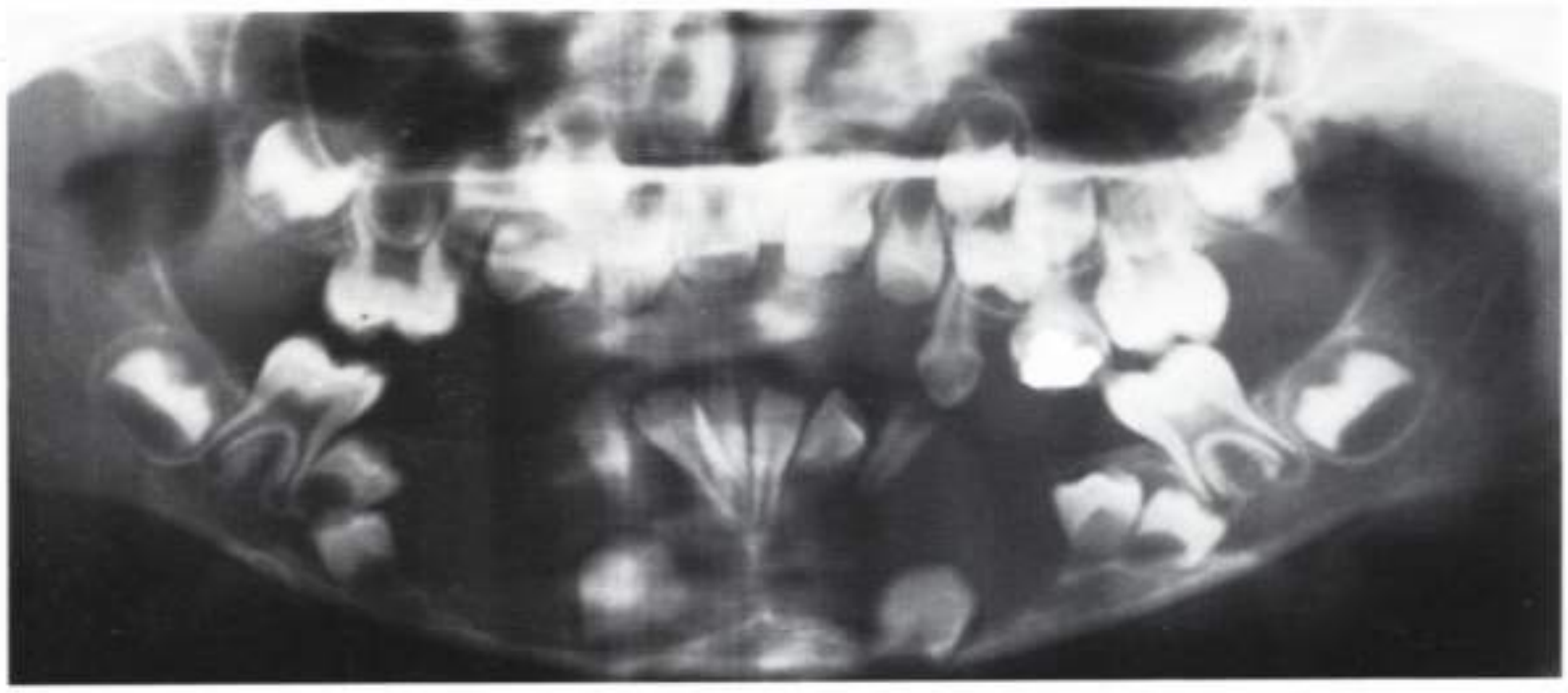
Severe premature loss of deciduous teeth is apparent in all four quadrants.



226 Teeth present after formation of the cyst
One year later, a large cyst has developed in the mandible, which extends continuously from the right to the left premolar region.

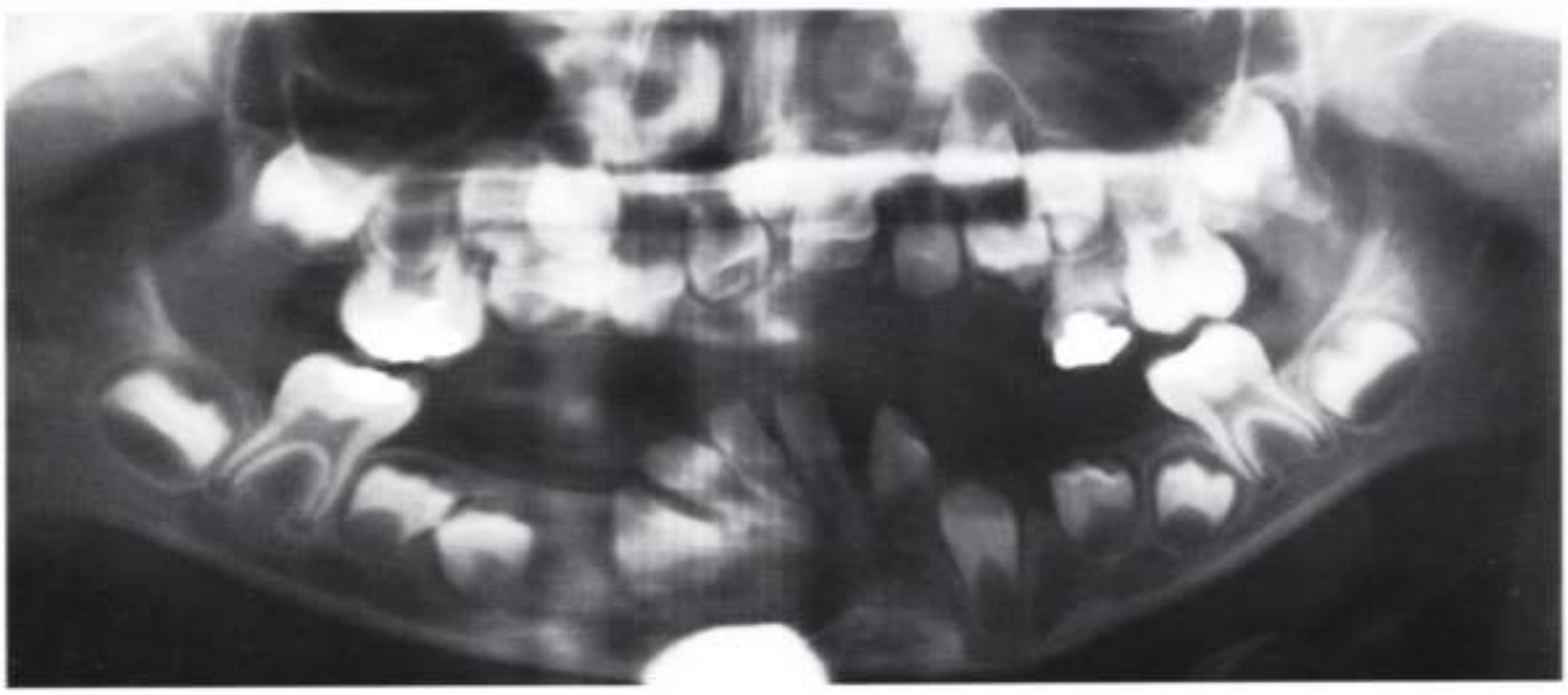
Due to expansion of the process, the germs of the lower canines and premolars were severely displaced.

The lower incisors erupted prematurely. The pressure exerted by the cyst on their roots forced them into a fan-like position.



227 Teeth present after treating the cyst
Five months after the cyst had been removed; the lower tooth germs have almost attained their previous position in the jaw.

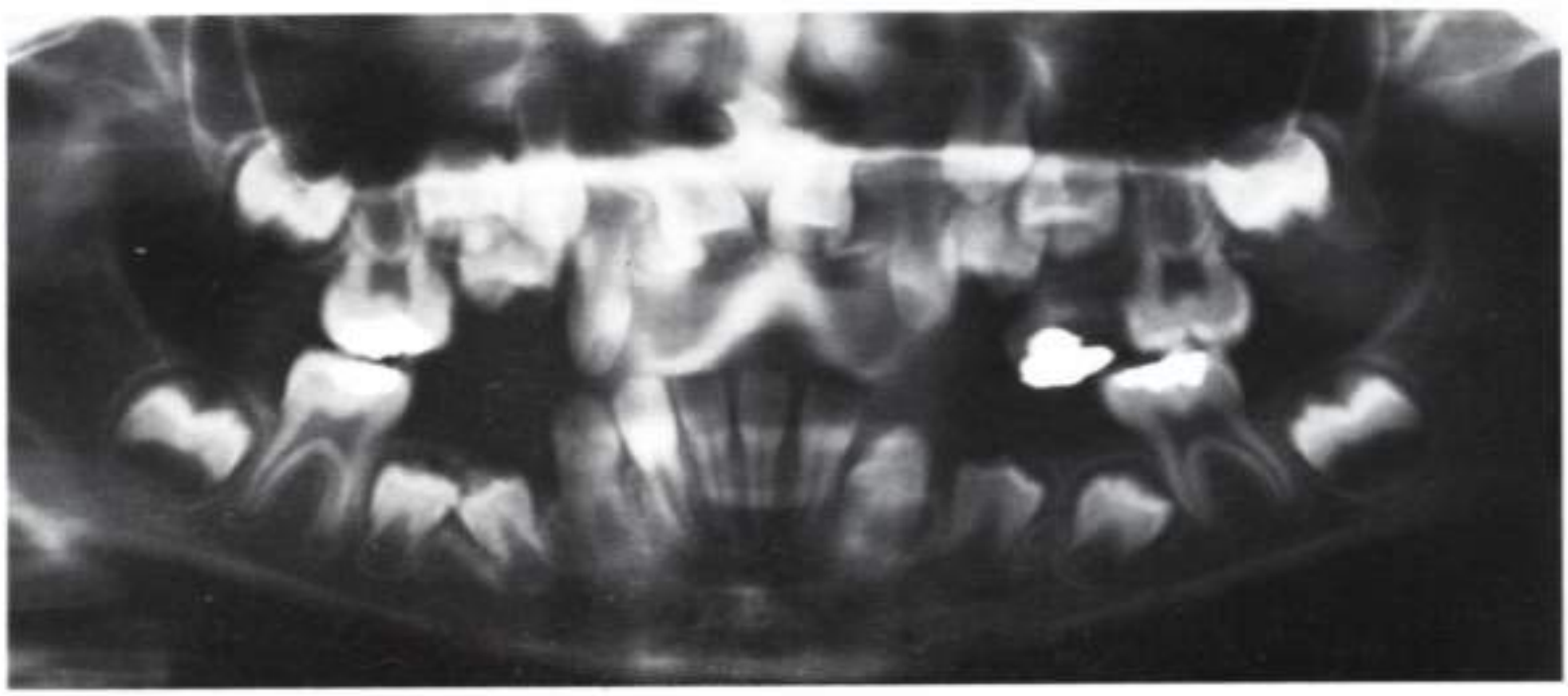
The crowns of the lower incisors are still flared distally, however.



228 Follow-up
Fifteen months after diagnosing the cyst, the lower anterior teeth have resumed their correct axial inclination. The gaps which remained between the premolar germs after treating the cyst have closed.

The bone defects in the anterior mandibular alveolar process caused the lower canines of this 6-year-old patient to erupt prematurely.

Note: Supernumerary tooth germs in the maxilla interfere with eruption of central incisors.



Case History

The first step in the assessment of orthodontic cases is the critical examination of the case history. The purpose of this is to understand the development of the malocclusion, so that by early elimination of the causative factors, correct therapy can be undertaken. Such an approach increases the likelihood of a more favorable prognosis and greater stability as compared to a purely symptomatic approach to orthodontic or dentofacial orthopedic treatment.

As a rule, the case history is usually assessed with the help of a special questionnaire. Questions related to the case history are divided into two parts:

- **Family history**
- **Patient history**

Hereditary malocclusions

229 Deep bite in the deciduous dentition

Most hereditary dysgnathias are already evident in the deciduous dentition. Dominantly inherited anomalies include mandibular prognathism, Class II, Division 2, some cases of distoclusion, skeletal open bite, and bimaxillary protrusion.

An excessive vertical development of the anterior maxillary gum pads in the newborn ("Schachtelbiss"; engl. "boxbite") is assessed as the early form of the congenital deep bite.

From the *family history,* one learns about certain malocclussions and other abnormalities (for instance, impaired nasal breathing) present in members of the same family.

A relatively large number of dysgnathias are inherited and transmitted through a dominant gene, whereas in cases of cleft lip and palate, it is mostly through a recessive gene.

The *patient's history* is divided into three parts. First is the *prenatal* period, during which the following are of interest: Nutritional disorders, diseases and accidents to the mother during pregnancy. The best-known example of this is the relationship between viral infection and cleft formation in the newborn.

The questions which relate to the birth include time of birth, the fetal position at birth, and complications. The most detailed part of the patient's own history is the *postnatal* development. The manner of feeding, as well as nutritional disturbances are noted (mineralization defects of the teeth). Questions regarding the eruption of the first deciduous tooth, the child's general development (initiation of talking, walking), and information concerning sucking and other "bad habits" are useful.

Accidents in childhood, the state of the deciduous dentition, and the early loss of primary teeth should also be noted.

Other more *generalized diseases* are of interest, in particular conditions which affect the development of the jaws (for instance, rickets, dysostoses). This aspect would also include all diseases which are important in influencing the type of breathing (colds, pneumonias, otitis, allergies). Further evidence of disturbed respiration includes the type of breathing during sleep (open mouth, snoring) as well as previous adenoidectomy and/or tonsillectomy. After adenoidectomy, the possibility of homeostatic adaptation must be considered.

Specific questions should include medical conditions which may limit orthodontic treatment (for example, diabetes mellitus, epilepsy, blood dyscrasias, rheumatic disease, allergies to nickel and acrylic).

Psychologic aspects of orthodontic treatment should be also discussed while taking the history and talking with the patient (motivation of the patient, also of parents in young patients, expectation with regard to treatment result). Such information is helpful to estimate future cooperation during treatment.

230 Bimaxillary protrusion

The hereditary component of this dentoalveolar abnormality is usually localized in the neuromuscular system.

Because of hereditary lip incompetence, the muscular equilibrium between tongue and lips is disturbed.

The labial inclination of the anterior teeth results from a relative hyperactivity of the tongue musculature.

Right: Weak tonus of the orbicularis oris muscle.

231 Drug-induced enamel dysplasia

Decalcification of six anterior teeth and first permanent molars in a 14-year-old patient. Clinical situation following tetracycline treatment for meningitis at the age of 2 years.

Teeth which had not yet calcified at the time of treatment for the meningitis are not affected (premolars and second molars).

232 Head and neck surgery

Dental condition of a 10-year-old patient after surgical closure of a bilateral cleft lip and palate, in the newborn and infant period.

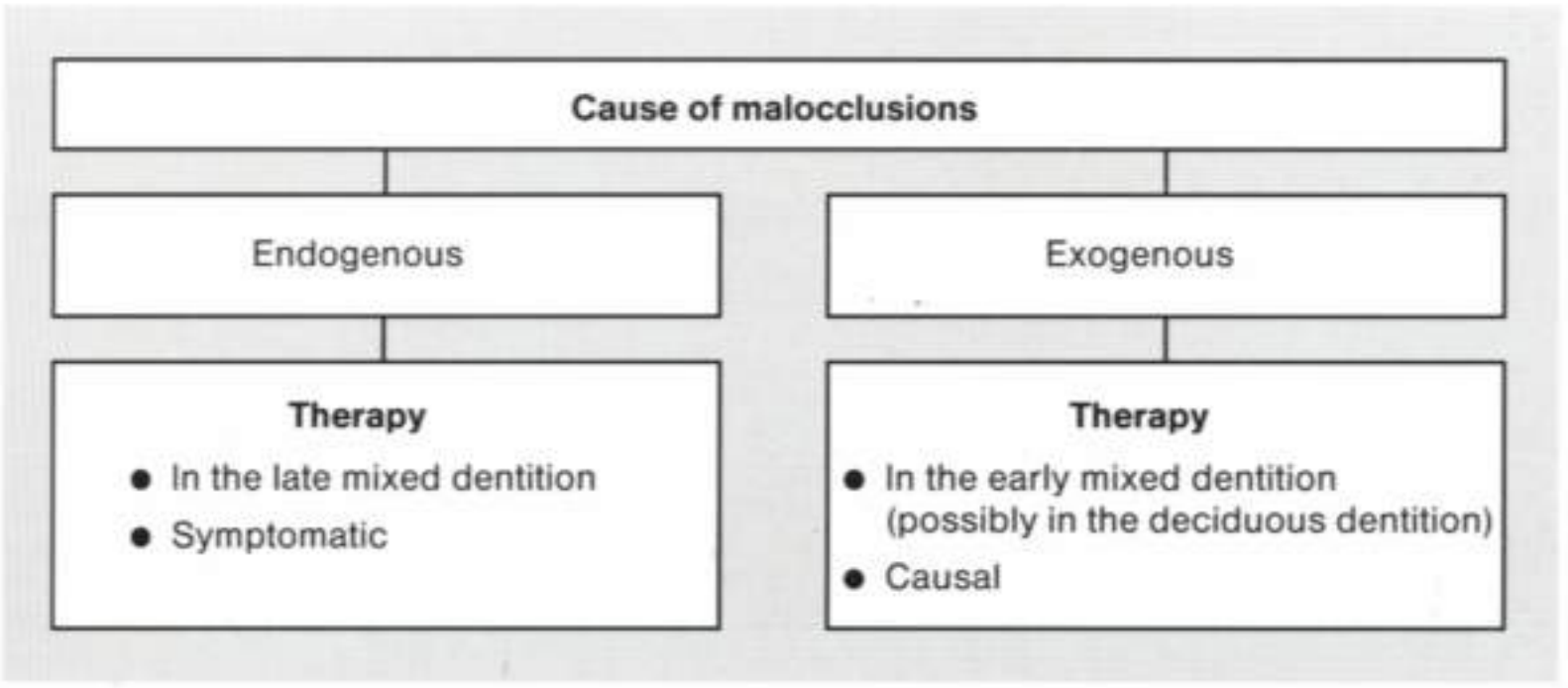
Scar tissue can further restrict sagittal and vertical maxillary growth, resulting in mandibular prognathism.

Interpretation of the Case History

In many cases, the findings of the patient's history may give some clues regarding the cause of the malocclusion and help in planning the necessary therapy. Together with the interpretation of the case history, one has to bear in mind that a *single etiologic factor does not exist.*

A combination of different endogenous and exogenous factors is responsible for the individual abnormality at a particular time. An inherited tendency may be present as well as the acquired malocclusion. The effect of a sucking habit is significantly less favorable in a vertical as compared with a horizontal growth tendency (see page 192).

The course of orthodontic therapy, and the stability of treatment results, may be affected if causative factors of the malocclusion have not been recognized.



233 Interpretation of the patient's history
A first impression of the cause of a malocclusion can be elicited from the patient's history, which may influence the timing of treatment as well as the therapeutic possibilities.

Acquired malocclusions and predispositions

234 Lip dysfunction in neutroclusion
Morphological relationship in a skeletal Class I case with lip dysfunction.

Right: The dyskinesia in this case results in only a slight change of the overjet.

235 Lip dysfunction in distoclusion
Morphological relationship in a Class II case with concomitant lip dyskinesia.

Right: Compared with Fig. 234: The functional soft-tissue disturbance leads to a greater overjet in the case of distoclusion.

Questionnaire – Case History

1) Family history

	Father	Mother	Siblings				Relatives			
Rickets (R), colds (C)										
Adenoids (A), mouth breathing (M)										
Adenoidectomy (AT), tonsillectomy (T)										
Cleft lip (L), jaw (J), or palate (P)										
Supernumerary teeth (S), missing teeth (MT)										
Protrusion (P), Class II, Division 2 (D), Class III (M)										
Open-bite (O), deep bite (D)										
Dental crowding										
Orthodontic treatment										
Miscellaneous:										

2) Patient history

Prenatal (course of pregnancy)

Diseases: Nutritional disorders: yes/no

Psychological problems: yes/no Medication: yes/no

Accidents: yes/no When: Type:

Birth

Premature – normal – late: Position:

Course of labor: Normal Forceps Cesarian section Suction cup

Weight: Length: Incubator: yes/no

Postnatal

Developmental state at birth: Normal / underdeveloped / hospitalization

Infant feeding: Breastfed up to month bottle-fed up to year spoon-fed after the month
fed solid foods after the month given the following additional foods after the month:

Vitamin D: Fluoride preparations: up to:

First tooth: month Learned to walk during the month Learned to speak during the month

Premature loss of deciduous teeth: yes/no Which teeth:

Sucking: Which finger right / left, pacifier, corner of the blanket From to years
NUK nipple: yes / no From to years

Parafunctions: Nail biting, clenching, bruxism

Sleeping habits: Position: Mouth opened / closed Snoring: yes / no

Diseases: Rickets – colds – pneumonia – otitis – asthma – allergies

Systemic diseases:

Allergies:

Adenoidectomy / tonsillectomy: At age of:

Accidents: Age: Type:

Teeth involved: yes / no Treatment:

Operations in the head / neck region:

Clinical Examination

The clinical findings are the basis of diagnostic procedures. The aim of the investigation is the recognition of the orthodontic problem from the patient's point of view as well as the examiner's, and to determine the need for treatment. Clinical findings are the prerequisite for the correct assessment and interpretation of the quantitative analyses, i.e. the *overall general* and the *specific clinical findings,* which serve as the foundation of treatment decisions.

General State

Examination of the constitution and physique of the patient, height and weight in relationship to the chronologic age and development of the facial skeleton.

An evaluation of the somatogram provides an indication of the general growth tendency. Further factors include the nutritional situation, assessment of mental development, and the dental and skeletal age.

Boys					Girls					Girls					Girls				
years	cm	± 2 σ	kg	± 2 σ	years	cm	± 2 σ	kg	± 2 σ	years	cm	± 2 σ	kg	± 2 σ	years	cm	± 2 σ	kg	± 2 σ
	176		67.2			165		56.0			165		56.0			165		56.0	
	175		65.0			164	13	54.5	+19.0		164		54.5	+19.0		164		54.4	+19.0
	174		63.0			163		53.5	−13.5		163		53.5	−13.5		163		53.5	−13.5
	173		61.0		14	162		52.5		14	162	13	52.5		14	162	13	52.5	
	172		59.0			161		50.8			161		50.8			161		50.8	
	171		57.8			160	13	49.2	+19.0		160	13	49.2	+19.0		160	13	49.2	+19.0
	170		56.7			159		47.6	−13.5		159		47.6	−13.5		159		47.6	−13.5
	169		55.6		13	158		46.0		13	158		46.0		13	158		46.0	
	168		54.5			157		45.1			157		45.1			157		45.1	
	167		53.5			156		44.2	+19.0		156		44.2	+19.0		156		44.2	+19.0
	166		52.5			155	14	43.3	−13.0		155	14	43.3	−13.0		155	14	43.3	−13.0
	165		51.6	+20.0		154		42.4			154		42.4			154		42.4	
	164		50.9	−14.0	12	153		41.5		12	153		41.5		12	153		41.5	
14	163	16	50.2			152		40.9			152		40.9			152		40.9	
	162		49.4			151		40.3			151		40.3			151		40.3	
	161		48.5			150	14	39.4	+16.5		150	14	39.4	+16.5		150	14	39.4	+16.5
	160		47.6			149		38.5	−11.0		149		38.5	−11.0		149		38.5	−11.0
	159	16	46.7	+20.0		148		37.5			148		37.5			148		37.5	
	158		45.8	−14.0	11	147		36.6		11	147		36.6		11	147		36.6	
	157		45.0			146		35.8			146		35.8			146		35.8	
13	156		44.2			145		35.2			145		35.2			145		35.2	
	155		43.5			144	13	34.6	+15.0		144	13	34.6	+15.0		144	13	34.6	+15.0
	154		42.7			143		34.1	−10.0		143		34.1	−10.0		143		34.1	−10.0
	153	14	42.0	+17.0		142		33.6			142		33.6			142		33.6	
	152		41.3	−12.0		141		33.0			141		33.0			141		33.0	
	151		40.6		10	140		32.5		10	140		32.5		10	140		32.5	
12	150		39.9			139		31.7			139		31.7			139		31.7	
	149		38.9			138		31.0			138		31.0			138		31.0	
	148		38.0			137	13	30.2	+11.0		137	13	30.2	+11.0		137	13	30.2	+11.0
	147	13	37.4	+15.5		136		29.4	− 8.0		136		29.4	− 8.0		136		29.4	− 8.0
	146		36.8	−11.0	9	135		28.9		9	135		28.9		9	135		28.9	
11	145		36.0			134		28.4			134		28.4			134		28.4	
	144		35.5			133		27.9			133		27.9			133		27.9	
	143		35.0			132	12	27.4	+10.0		132	12	27.4	+10.0		132	12	27.4	+10.0
	142	12	34.4	+11.5		131		26.8	− 7.5		131		26.8	− 7.5		131		26.8	− 7.5
	141		33.9	− 8.5	8	130		26.3		8	130		26.3		8	130		26.3	
10	140		32.4			129		26.0			129		26.0			129		26.0	
	139		31.7			128		25.6			128		25.6			128		25.6	
	138		31.1			127	12	25.1	+ 8.0		127	12	25.1	+ 8.0		127	12	25.1	+ 8.0
	137	12	30,5	+10.5		126		24.6	− 7.5		126		24.6	− 7.5		126		24.6	− 7.5
	136		30,0	− 7.5		125		24.1			125		24.1			125		24.1	
9	135		29.6		7	124		23.6		7	124		23.6		7	124		23.6	
	134		29.1			123		23.2			123		23.2			123		23.2	
	133		28.5			122		22.8			122		22.8			122		22.8	
	132		28.0	+ 8.5		121	12	22.4	+ 5.0		121	12	22.4	+ 5.0		121	12	22.4	+ 5.0
	131	11	27.4	− 6.5		120		22.0	− 3.5		120		22.0	− 3.5		120		22.0	− 3.5
	130		26.9			119		21.5			119		21.5			119		21.5	
8	129		26.4			118		21.1		6	118		21.1		6	118		21.1	

236 Somatogram

Left: Registration of chronologic age, height (in cm), weight (in kg) at the time of examination.

Comparison of the data to average values. The tables are different for boys and girls.

Right: Data are underlined in their respective columns. Physical development is taken as normal when lines are approximately horizontal.

Near right: If pathologic differences from the norm of the order of ± 2 standard deviations relating to the patient's chronologic age, height, and weight exist, as occurs in dwarfism, gigantism, obesity, or anorexia, a medical examination is required (*Kunze* and *Murken,* University of Munich, 1974).

Dental Age

Evaluation of the dental status is of great importance for the prognostic assessment of dental development.

Chronologic and dental age are synchronous in the normal patient. A child is labeled as an *early* or *late developer* if there is a difference of ±2 years from the average value. If the chronologic age of the patient is younger than the dental age, one can rely on increased growth to a greater degree than when dental age is retarded in relation to the chronologic age (and possibly biologic age).

Dental age can be determined by two different methods:

- Stage of eruption
- Stage of tooth mineralization on radiograph

Determination of *dental age from observation of eruption* has been the only method available (Fig. 238) for a long time. In most instances, it is fairly reliable. In certain cases, however, the accuracy of the method is limited (Figs. 239–243). During the quiescent periods in eruption, this approach is inadequate.

237 Timetable of dental development of the primary and permanent dentition

Statement of average figures according to *Logan* and *Kronfeld* (modified by *McCall* and *Schour*).

Sequence and timing of eruption of the permanent dentition are genetically determined and ethnically different, but are scarcely influenced by endocrine disturbance. Girls are slightly more advanced.

Deciduous teeth in the maxilla*

Tooth	Start of hard tissue formation	End of enamel formation	Eruption	Root formation complete
51/61	4 mo. in utero	1½ mo.	7½ mo.	1½ y.
52/62	4½ mo. in utero	2½ mo.	9 mo.	2 y.
53/63	5 mo. in utero	9 mo.	18 mo.	3¼ y.
54/64	5 mo. in utero	6 mo.	14 mo.	2½ y.

*Mandibular teeth usually develop before maxillary teeth.

Permanent teeth in the maxilla*

Tooth	Start of hard tissue formation	End of enamel formation	Eruption	Root formation complete
11/21	3– 4 mo.	4– 5 y.	7– 8 y.	10 y.
12/22	10–12 mo.	4– 5 y.	8– 9 y.	11 y.
13/23	4– 5 mo.	6– 7 y.	11–12 y.	13–15 y.
14/24	1½–1¾ y.	5– 6 y.	10–11 y.	12–13 y.
15/25	2–2¼ y.	6– 7 y.	10–12 y.	12–14 y.
16/26	at birth	2½– 3 y.	6– 7 y.	9–10 y.
17/27	2½– 3 y.	7– 8 y.	12–13 y.	14–16 y.
18/28	7– 9 y.	12–16 y.	17–21 y.	18–25 y.

*Mandibular teeth develop a few months to ½–1 year before the maxillary teeth.

Estimation of dental age from dental eruption

238 Correlation table of dental age and number of erupted teeth

Estimation of dental age for boys and girls separate (*Matiegka* and *Lukášová*).

The dental age is determined from tables by comparison of the number of erupted teeth with average values.

Average age of intraoral emergence of the teeth of single dental groups

Boys	1	2	3	4
Inc. centr.	*)	*)	6:08	7:04
Inc. lat.	6:11	7:03	7:11	8:06
Canine	10:00	10:07	11:02	11:10
Premolar I	9:01	9:01	10:04	11:01
Premolar II	10:01	10:07	11:02	11:10
Molar I	*)	*)	*)	*)
Molar II	10:09	11:02	11:09	12:05

Girls	1	2	3	4
Inc. centr.	*)	*)	*)	7:01
Inc. lat.	6:07	7:00	7:05	8:00
Canine	9:02	9:10	10:05	11:02
Premolar I	8:11	9:04	9:11	10:05
Premolar II	9:10	10:02	10:09	11:03
Molar I	*)	*)	*)	*)
Molar II	10:05	10:10	11:04	12:00

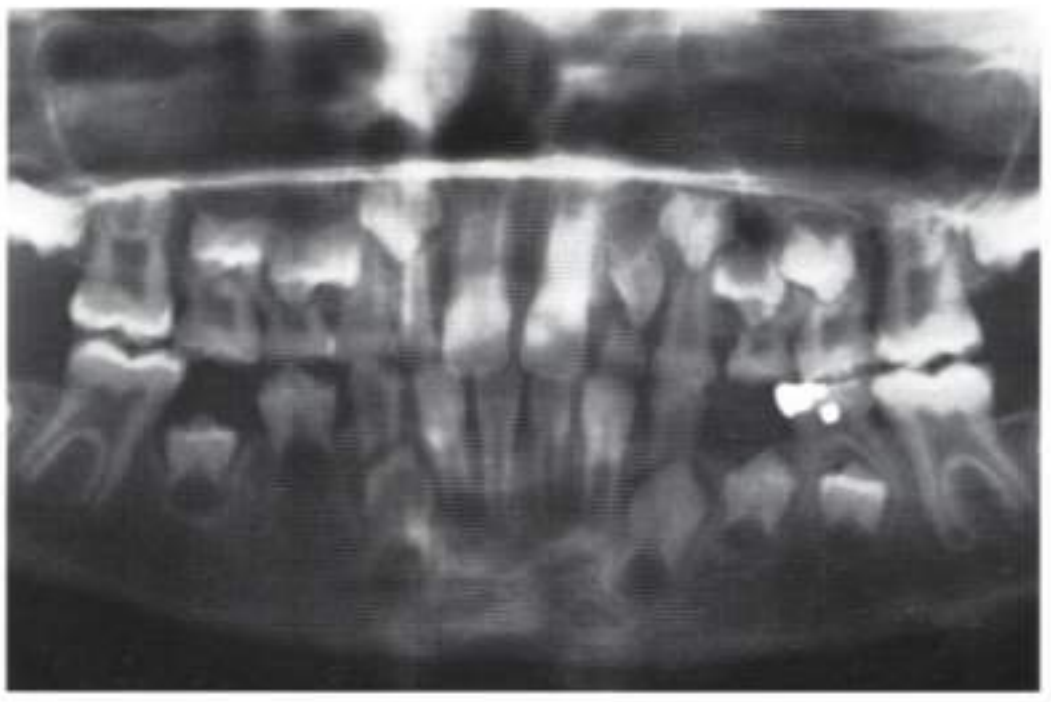
Dates given in years : months
*) Eruption occurs earlier than could be determined in this study.

239 Accelerated eruption

Accelerated eruption of the lower right premolars after early extraction of deciduous molars.

Right: Insufficient root development is characteristic of premature eruption.

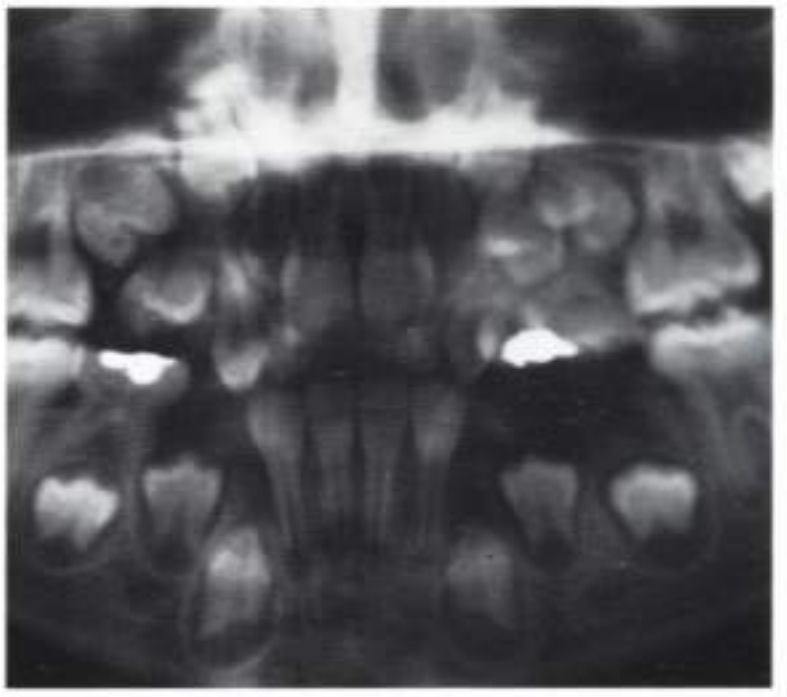
During the intraoral eruption stage, the tooth usually has one-third of its final root length.



240 True delay of eruption
Retarded change to permanent dentition as a late sequela of rickets.

Intraoral dental status of a 10-year-old with mineralization defects of the upper central incisors and the four lower front teeth as a symptom of vitamin D deficiency at the age of 2 years.

Right: Panoramic radiograph. Discrepancy between chronological (10 years) and dental age (7 years and 11 months).



241 Retarded eruption
The cause of delayed eruption of the upper incisors is deficient space in the upper anterior region in this 8-year-old patient.

Right: The radiograph shows the position of the tooth germs in the upper anterior region. Undermining resorption of the deciduous lateral incisors by the central permanent incisors as characteristic feature of a primary dental crowding.

242 False retarded eruption
Atypical eruption; in comparison with the opposite side, delayed eruption of the upper left permanent incisors and the left canine in a 13-year-old patient.

Right: Displacement of tooth germs following trauma to the primary teeth, causing intrusion of the upper left deciduous incisors, at 5 years of age.

243 Factors determining tooth eruption and dental age
Table showing the different local and systemic factors influencing dental development.

Left: Accelerating factors.

Right: Retarding factors.

Acceleration in dental development and eruption timing		Retardation in dental development and eruption timing	
True	• Endocrine disturbance • Diabetes mellitus	**True**	• Severe organic disease • Prolonged periods of deficiency • Endocrine disturbances • Bone disease • Environmental influence
False	• Early loss of deciduous teeth • Inflammatory processes of alveolar bone	**False**	• Post-traumatic situation • Alveolar bone hyperplasia (Leontiasis ossea) • Fibrous gingival hyperplasia (Elephantiasis gingivae)

When determining dental age radiographically according to the *stages of germination,* the degree of development of individual teeth is compared to a fixed scale (see Fig. 244).

For age determination, one does not rely on the last stage of tooth formation but on the entire process of dental mineralization. This renders the estimation of age more accurate. The procedure can be used for the entire deciduous and mixed dentition period, and is not influenced by early loss of deciduous teeth. The calculation is made using a point evaluation system (Demirjian et al. 1973, Schopf 1970). Each tooth is given a point value according to its state of development (Fig. 246). The sum of individual points gives the developmental value, which can be transferred into the dental age with the aid of standard tables. The smaller the sum of points, the younger the dental age; the higher the sum, the older the dental age (Fig. 247).

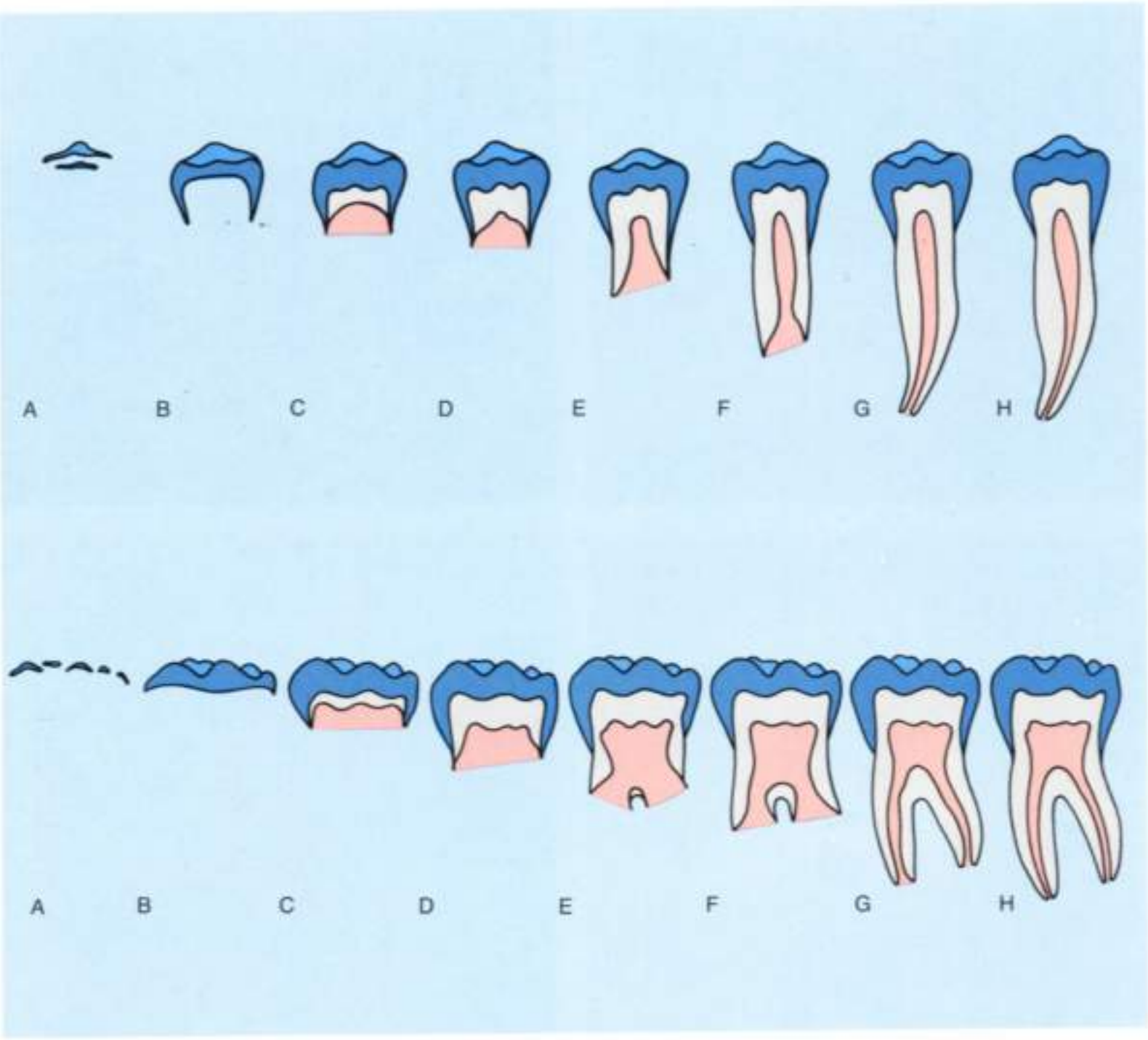
Experience shows that the method is sufficiently accurate if the stage of mineralization of teeth 1–7 in the left lower quadrant is examined. The procedure is not valid for patients with several congenitally absent teeth.

Dental age determination according to the stage of mineralization

244 Nine relevant stages of dental development

O Tooth germ without signs of calcification.
A Calcification of single occlusal points without fusion of different calcifications.
B Fusion of mineralization points; the contour of the occlusal surface is recognizable.
C Calcification of the crown is complete; beginning of dentin deposits.
D Crown formation is complete up to the cementoenamel junction.
E Root length shorter than crown height.
F Root length larger than crown height.
G Root formation finished. Apical foramen still open.
H Apical foramen is closed.
(*Demirjian* et al., 1973)

Above: Developmental stages of a singlerooted tooth.
Below: Developmental stages of a multirooted tooth.



245 Case example

In this girl aged 7 years and 8 months, the seven permanent tooth germs in the lower left quadrant show the following developmental stages:
M_2 = Stage D
M_1 = Stage G
P_2 = Stage C
P_1 = Stage D
C = Stage E
I_2 = Stage G
I_1 = Stage H

This gives a point sum of 71.5 and a dental age of 7.7 years (see Fig. 246).

246 Scores of different dental formation stages

The point value of specific stages of mineralization depends on the tooth type and patient's gender.

The table was made for the left mandibular quadrant (*Demirjian* et al., 1973)

Boys	Stage								
Tooth	**0**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
M_2	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M_1				0.0	8.0	9.6	12.3	17.0	19.3
PM_2	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM_1			0.0	3.5	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I_2					3.2	5.2	7.8	11.7	13.7
I_1					0.0	1.9	4.1	8.2	11.8

Girls	Stage								
Tooth	**0**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
M_2	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M_1				0.0	4.5	6.2	13.5	14.0	16.2
PM_2	0.0	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM_1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.2	5.6	10.3	11.6	12.4
I_2				0.0	3.2	5.6	8.0	12.2	14.2
I_1					0.0	2.4	5.1	9.3	12.9

Note: Stage 0 = no mineralization

247 Conversion chart for dental age determination, calculated according to the score-system of dental formation

The overall figure for assessment of dental age is obtained by adding together the separate values for 7 teeth in the lower left quadrant (y = years, ♂ = boys, ♀ = girls).

If one of the teeth is missing, the corresponding tooth on the opposite side is used for the assessment (*Demirjian* et al., 1973).

Age	Points		Age	Points		Age	Points		Age	Points	
y	♂	♀	y	♂	♀	y	♂	♀	y	♂	♀
3.0	12.4	13.7	6.3	36.9	41.3	9.6	87.2	90.2	12.9	95.4	97.2
.1	12.9	14.4	.4	36.9	41.3	.7	87.7	90.7			
.2	13.5	15.1	.5	39.2	43.9	.8	88.2	91.1	13.0	95.6	97.3
.3	14.0	15.8	.6	40.6	45.2	.9	88.6	91.4	.1	95.7	97.4
.4	14.5	16.6	.7	42.0	46.7				.2	95.8	97.5
.5	15.0	17.3	.8	43.6	48.0	10.0	89.0	91.8	.3	95.9	97.6
.6	15.6	18.0	.9	45.1	49.5	.1	89.3	92.3	.4	96.0	97.7
.7	16.2	18.8				.2	89.7	92.3	.5	96.1	97.8
.8	17.0	19.5	7.0	46.7	51.0	.3	90.0	92.6	.6	96.2	98.0
.9	17.6	20.3	.1	48.3	52.9	.4	90.3	92.9	.7	96.3	98.1
			.2	50.0	55.5	.5	90.6	93.2	.8	96.4	98.2
4.0	18.2	21.0	.3	52.0	57.8	.6	91.0	93.5	.9	96.5	98.3
.1	18.9	21.8	.4	54.3	61.0	.7	91.3	93.7			
.2	19.7	22.5	.5	56.8	65.0	.8	91.6	94.0	14.0	96.6	98.3
.3	20.4	23.2	.6	59.6	68.0	.9	91.8	94.2	.1	96.7	98.4
.4	21.0	24.0	.7	62.5	71.8				.2	96.8	98.5
.5	21.7	24.8	.8	66.0	75.0	11.0	92.0	94.5	.3	96.9	98.6
.6	22.4	25.6	.9	69.0	77.0	.1	92.2	94.7	.4	97.0	99.5
.7	23.1	26.4				.2	92.5	94.9	.5	97.1	98.8
.8	23.8	27.2	8.0	71.6	78.8	.3	92.7	95.1	.6	97.2	98.9
.9	24.6	28.0	.1	73.5	80.2	.4	92.9	95.3	.7	97.3	99.0
			.2	75.1	81.2	.5	93.1	95.4	.8	97.4	99.1
5.0	25.4	28.9	.3	76.4	82.2	.6	93.3	95.6	.9	97.5	99.1
.1	26.2	29.7	.4	77.7	83.1	.7	93.5	95.8			
.2	27.0	20.5	.5	79.0	84.0	.8	93.7	96.0	15.0	97.6	99.2
.3	27.8	31.3	.3	80.2	84.8	.9	93.9	96.2	.1	97.7	99.3
.4	28.6	32.1	.7	81.2	85.3				.2	97.8	99.4
.5	29.5	33.0	.8	82.0	86.1	12.0	94.0	96.3	.3	97.8	99.5
.6	30.3	34.0	.9	82.8	86.7	.1	94.2	96.4	.4	97.9	99.5
.7	31.1	35.0				.2	94.4	96.5	.5	98.0	99.6
.8	31.8	36.0	9.0	83.6	87.2	.3	94.5	96.6	.6	98.1	99.6
.9	32.6	37.0	.1	84.3	87.8	.4	94.6	96.7	.7	98.2	99.7
			.2	85.0	88.3	.5	94.8	96.8	.8	98.2	99.8
6.0	33.6	38.0	.3	85.6	88.8	.6	95.0	96.9	.9	98.3	99.9
.1	34.7	39.1	.4	86.2	89.3	.7	95.1	97.0			
.2	35.8	40.2	.5	86.7	89.8	.8	95.2	97.1	16.0	98.4	100.0

Biological Age and Hand Radiograph

Chronological age is often not sufficient for assessing the developmental stage and somatic maturity of the patient, so that the biologic age has to be determined.

The biologic age is determined from the skeletal, dental, and morphologic age and the onset of puberty.

Assessment of the skeletal age is often made with the help of a hand radiograph which can be considered the "biological clock." For the analysis of skeletal maturity up to the age of 9 years, the stage of mineralization of the carpal bones must be determined; thereafter, the development of metacarpal bones and phalanges should be evaluated (Fig. 248). For the evaluation of the hand radiograph, various indicators regarding development and maturity are established which occur regularly in a definite sequence during skeletal development.

In addition to evaluation of the hand radiograph using standard tables and the atlas of Greulich and Pyle (1959), the analysis of Björk (1972) has been useful

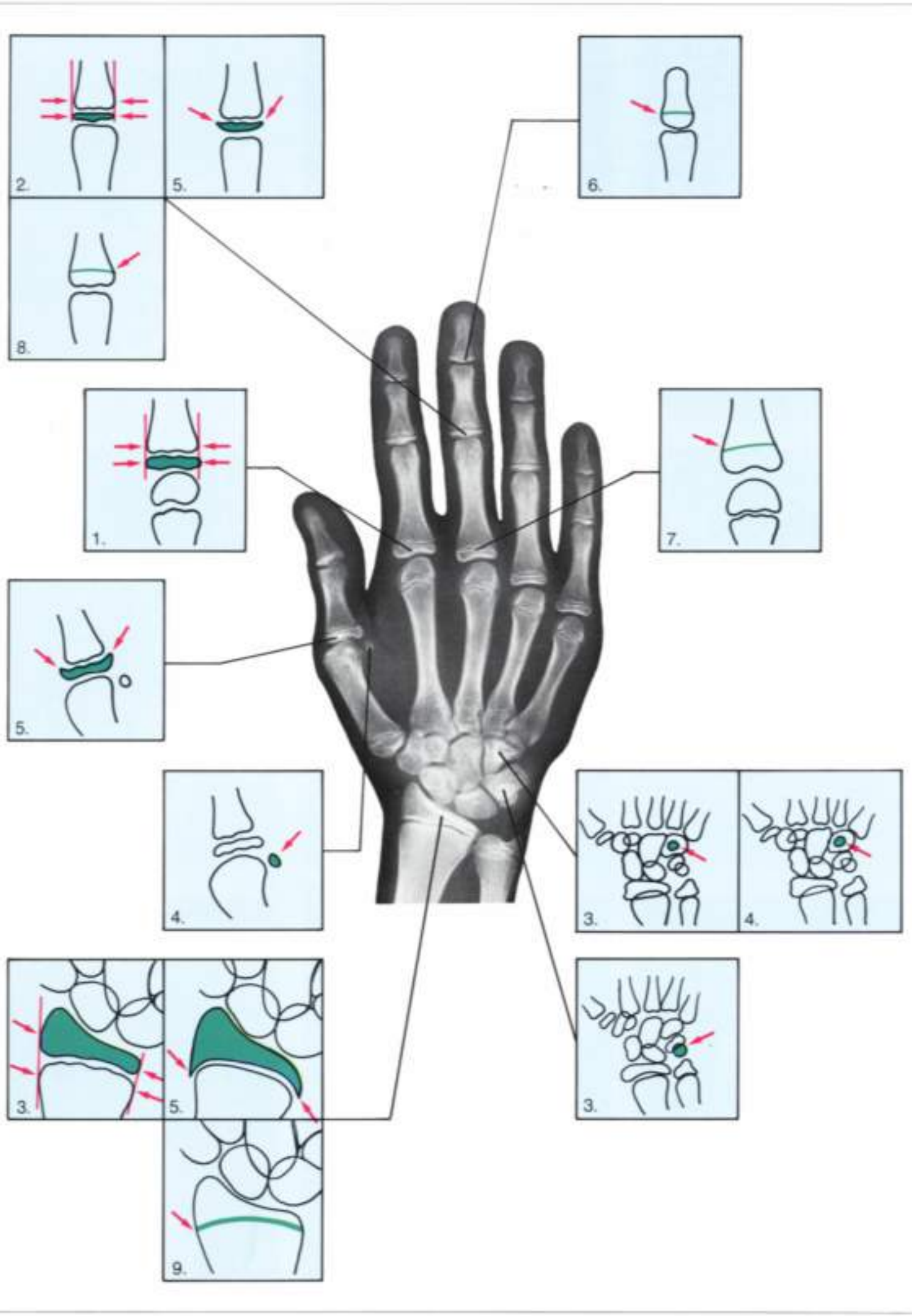
248 Topographic anatomy of the skeleton of the hand

1 = Epiphysis of the thumb
2 = Epiphysis of the proximal phalanx of the thumb
3 = Sesamoid of the adductor brevis muscle at the metacarpophalangeal joint of the thumb
4 = Epiphysis of the distal phalanx of the index finger
5 = Epiphysis of the middle phalanx of the index finger
6 = Epiphysis of the proximal phalanx of the index finger
7 = Epiphysis of the distal phalanx of the middle finger
8 = Epiphysis of the middle phalanx of the middle finger
9 = Epiphysis of the proximal phalanx of the ring finger
10 = Epiphysis of the distal phalanx of the ring finger
11 = Epiphysis of the middle phalanx of the ring finger
12 = Epiphysis of the proximal phalanx of the ring finger
13 = Epiphysis of the distal phalanx of the little finger
14 = Epiphysis of the middle phalanx of the small finger
15 = Epiphysis of the proximal phalanx of the little finger
16 = Epiphysis of the first metacarpal bone
17 = Epiphysis of the second metacarpal bone
18 = Epiphysis of the third metacarpal bone
19 = Epiphysis of the fourth metacarpal bone
20 = Epiphysis of the fifth metacarpal bone
21 = Trapezium
22 = Trapezoid bone
23 = Capitate bone
24 = Hamate bone
25 = Hamular process of the hamate bone
26 = Triquetral bone
27 = Pisiform bone
28 = Lunate bone
29 = Scaphoid bone
30 = Distal epiphysis of the radius
31 = Distal epiphysis of the ulna

in orthodontics and dentofacial orthopedics which divides the maturation process of bones of the hand between the 9th to the 17th year into eight developmental stages.

The delineation of single developmental stages is facilitated by inclusion of six further ossification centers (Grave and Brown 1976) whereby the skeletal age can be determined more accurately (Fig. 249). The different stages of maturation are shown in Figs. 250–258.

Since ossification of the hand bones shows considerable inter-individual variations, skeletal age determination from hand radiographs alone may not be accurate.



249 Maturation indicators of the hand bones for determining skeletal age from the 8th to the 18th year
Presence of 9 developmental stages according to *Björk* (1972), *Grave* and *Brown* (1976). The ossification events are localized in the area of the phalanges, carpal bones, and radius (R).

Growth stages of the fingers are assessed according to the relationship between the epiphyses and the diaphyses.

There are three stages of ossification of the phalanges:

First stage:
Epiphysis shows the same width as the diaphysis (=).

Second stage:
Capping stage (= cap); the epiphysis surrounds the diaphysis like a cap.

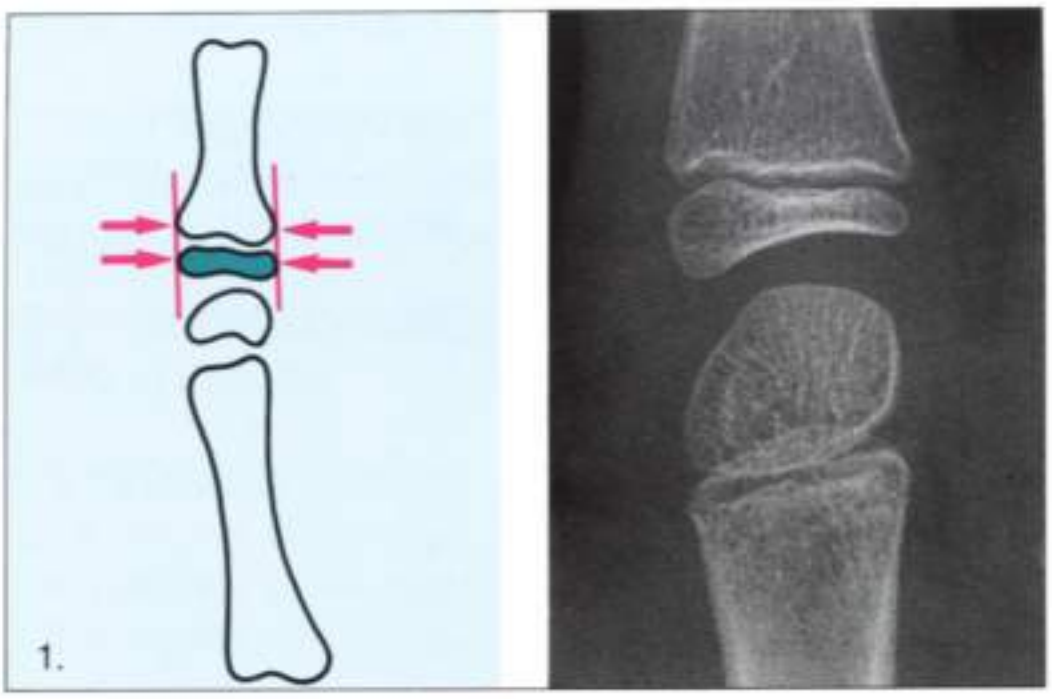
Third stage:
U-Stage (= u); bony fusion of epiphysis and diaphysis.

For assessment of maturity in the area of the phalanges, fingers 1–5, beginning with the thumb, are labeled.

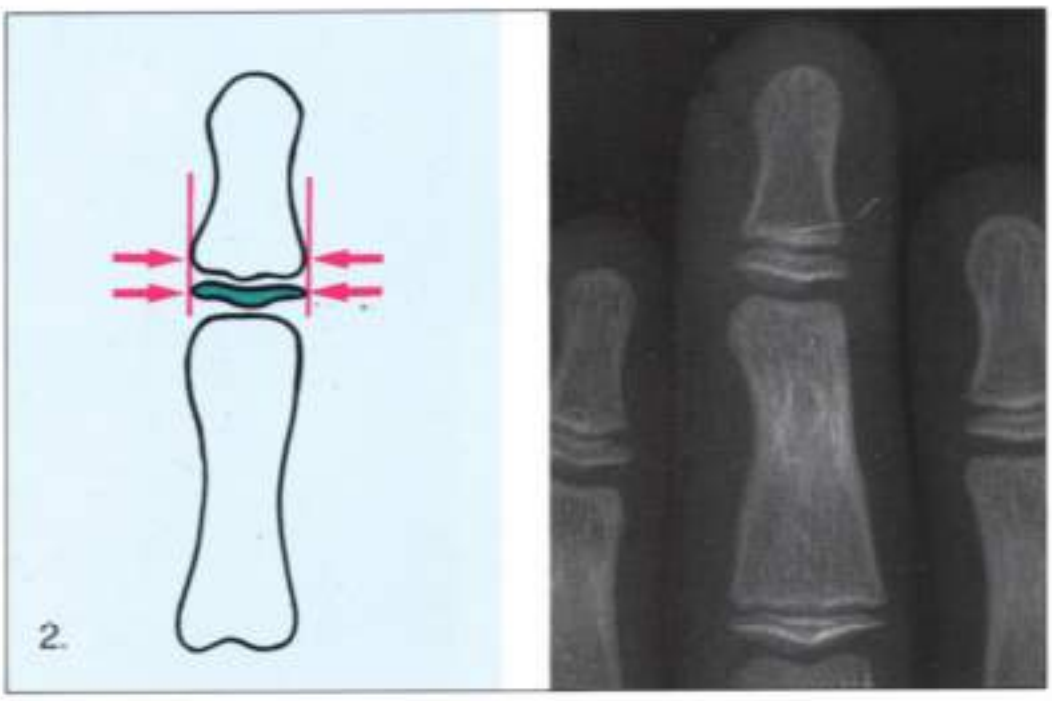
250 First stage of maturation; analysis of hand radiographs according to Björk, Grave, and Brown:
PP2 = – Stage
Diagram and radiographs of ossification stage.

The epiphysis of the proximal phalanx of the index finger (PP2) has the same width as the diaphysis.

This stage occurs approximately 3 years before the peak of the puberal growth spurt.



251 Second stage:
MP3 = – Stage
Epiphysis of the middle phalanx of the middle finger (MP3) is of the same width as the diaphysis.

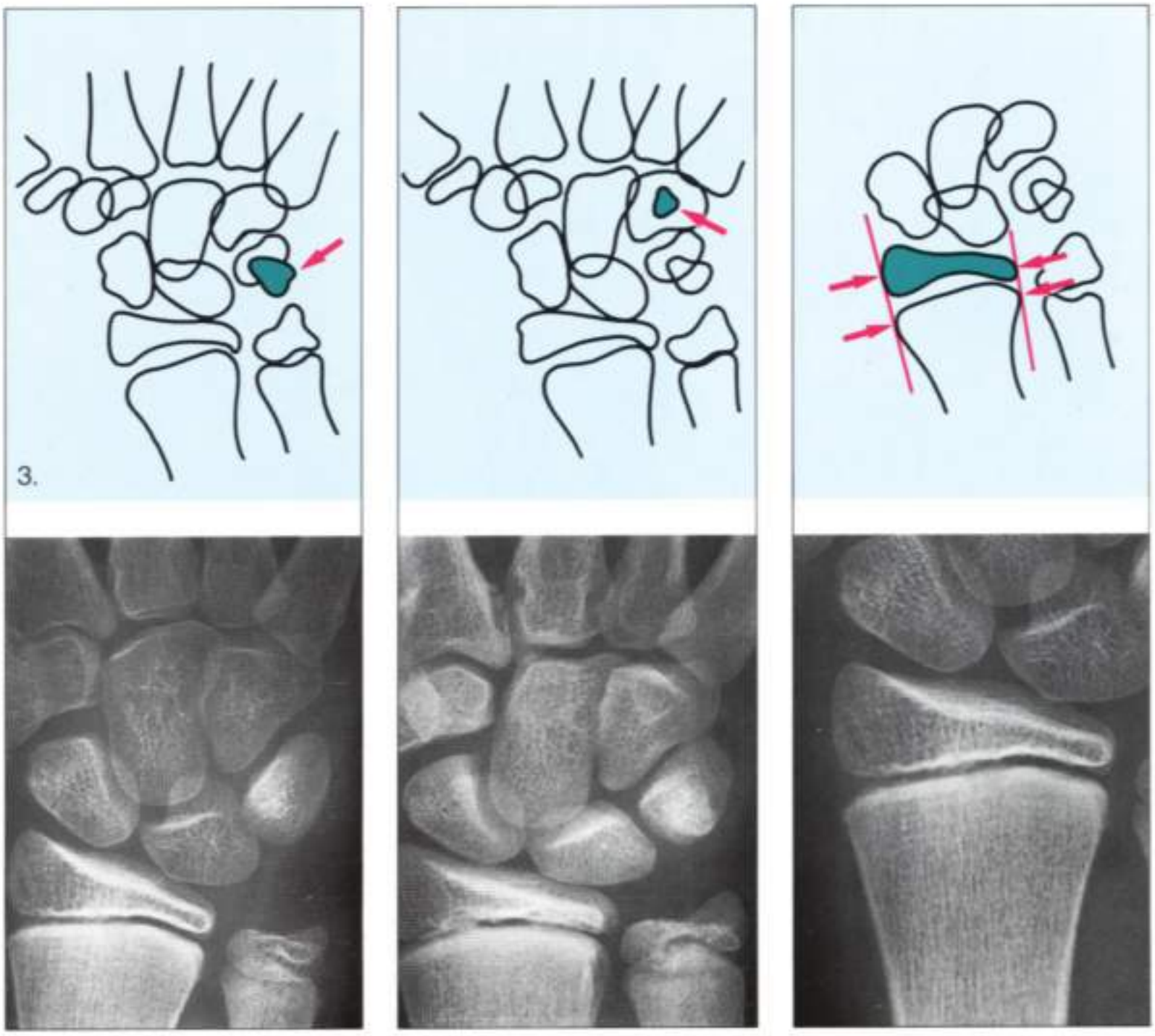


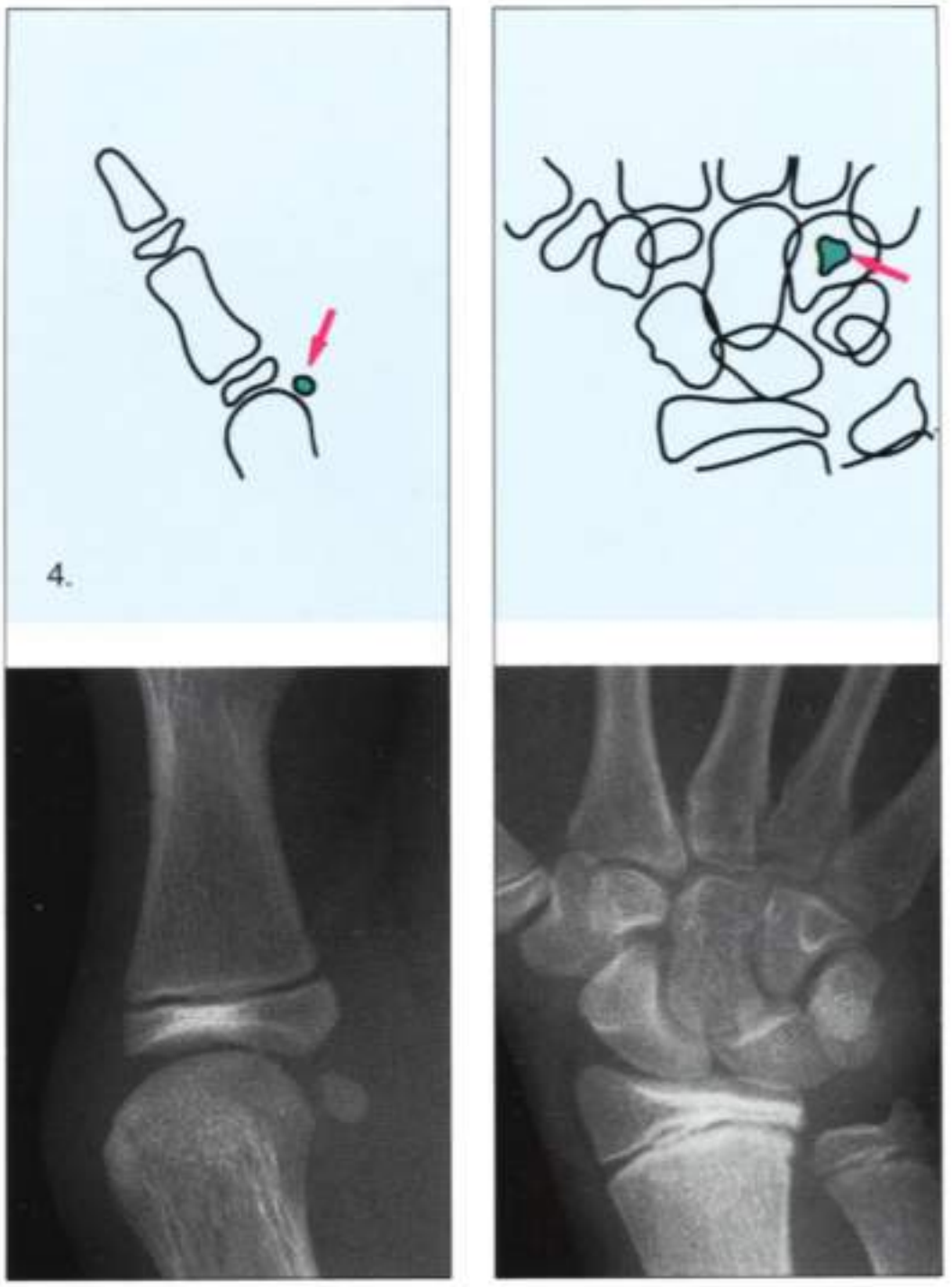
252 Third stage:
Pisi-, H1-, and R = – Stage
This stage of development can be identified by three distinct ossification areas; these show individual variations but appear at the same time during the process of maturation.

Pisi-stage = Visible ossification of the pisiforme.

H1-stage = Ossification of the hamular process of the hamatum.

R = -stage, same width of epiphysis and diaphysis of the radius.



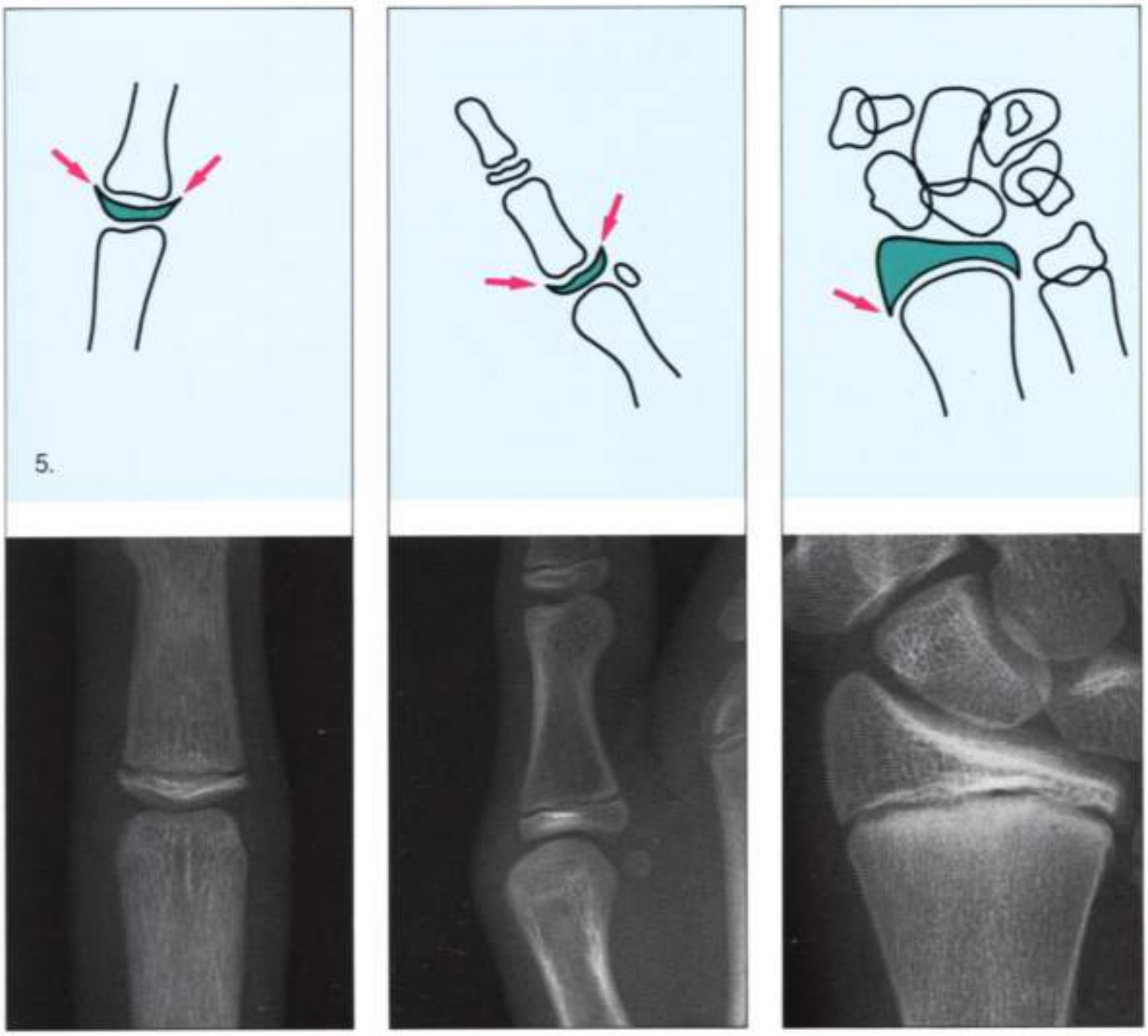


253 Fourth stage:
S- and H2-stage

S-stage = First mineralization of the ulnar sesamoid bone of the metacarpophalangeal joint of the thumb.

H2-stage = Progressive ossification of the hamular process of the hamatum.

The fourth stage is reached shortly before or at the beginning of the puberal growth spurt.



254 Fifth stage:
$MP3_{cap}$-, $PP1_{cap}$-, and R_{cap}-stage

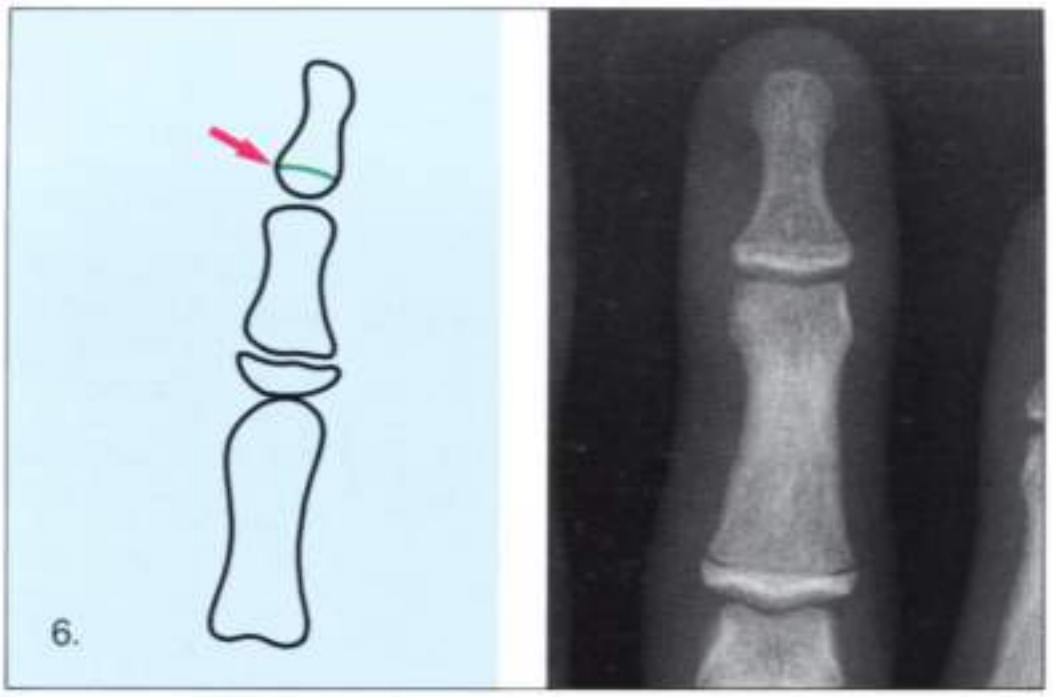
During this stage, the diaphysis is covered by the cap-shaped epiphysis.

In the $MP3_{cap}$-stage, the process begins at the middle phalanx of the third finger;
in the $PP1_{cap}$-stage, at the proximal phalanx of the thumb;
and in the R_{cap}-stage, at the radius.

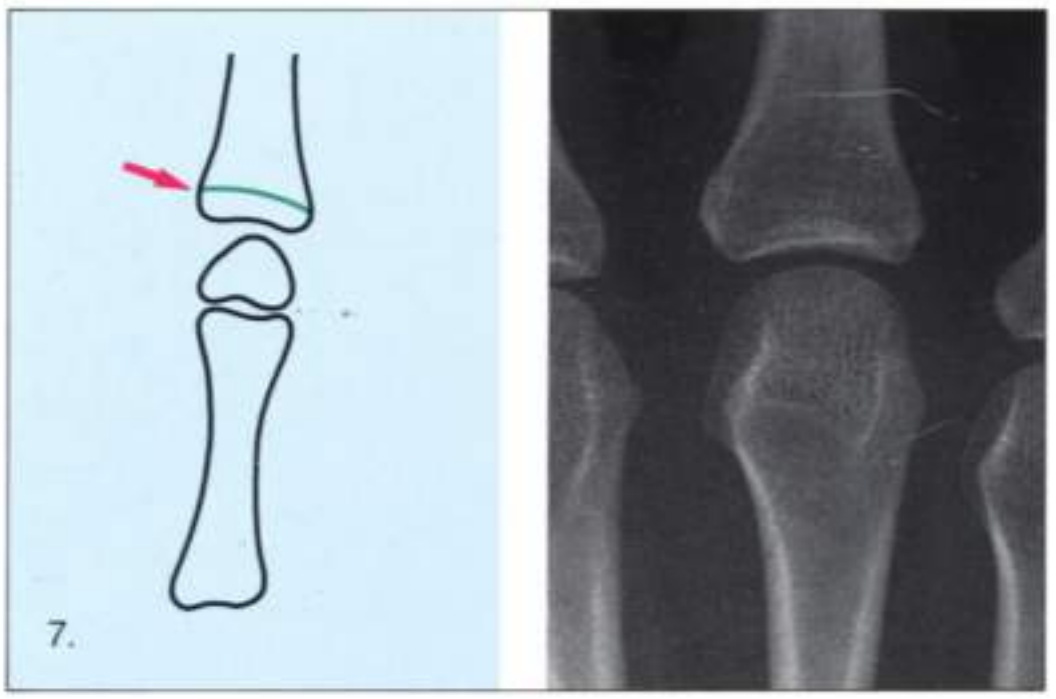
This stage of ossification marks the peak of the puberal growth spurt.

255 Sixth stage:
$DP3_u$-stage
Visible union of epiphysis and diaphysis at the distal phalanx of the middle finger (DP3).

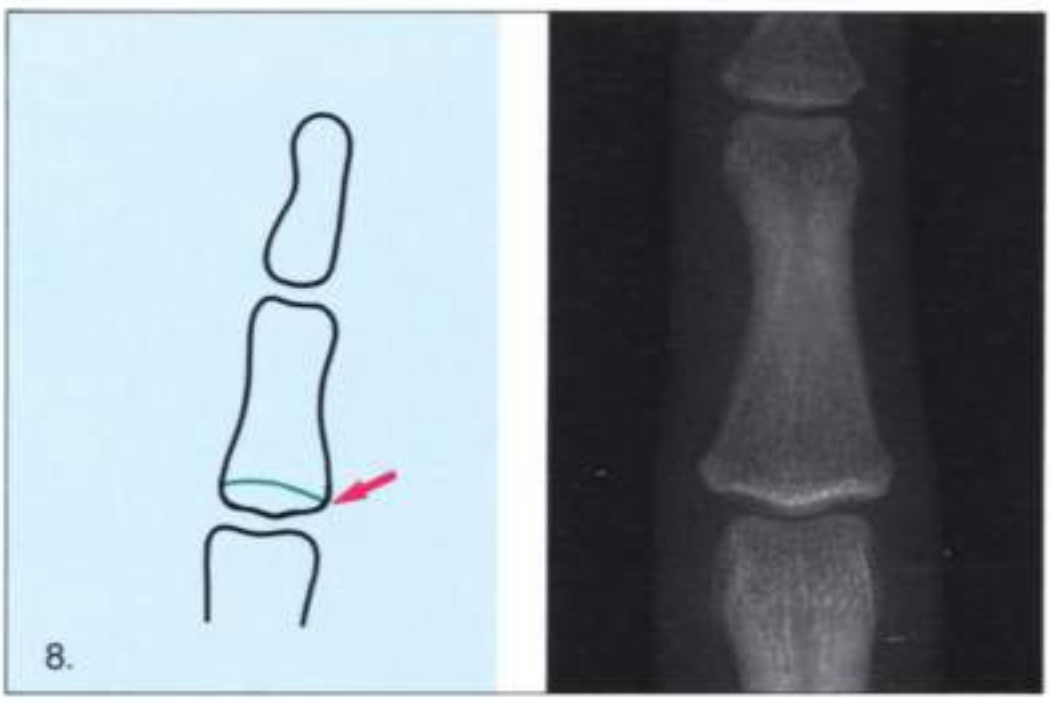
This stage of development constitutes the end of puberal growth.



256 Seventh stage:
$PP3_u$-stage
Visible union of epiphysis and diaphysis at the proximal phalanx of the little finger (PP3).



257 Eighth stage:
$MP3_u$-stage
Union of epiphysis and diaphysis at the middle phalanx of the middle finger is clearly visible (MP3).



258 Ninth stage:
R_u-stage
Complete union of epiphysis and diaphysis of the radius.

The ossification of all the hand bones is completed and skeletal growth is finished.

Growth Rhythm

The puberal growth spurts are dependent on gender and vary in their relationship to the chronologic age. These variations determine the speed as well as the duration of the growth processes. In girls, puberal growth spurts usually start between the ages of 10 and 12 years, in boys between 12 and 14 years with variations of 3 to 6 years on either side.

A *disturbance of growth rhythm* is only considered if a difference of ±2 years between chronologic and biologic age is noticed.

The essential criteria for skeletal development are: a) Growth within a definite time period, and b) development to maturity.

Growth can be measured in millimeters; time periods can be determined in weeks, months, or years; the maturity process, however, can only be ascertained by ossification assessment.

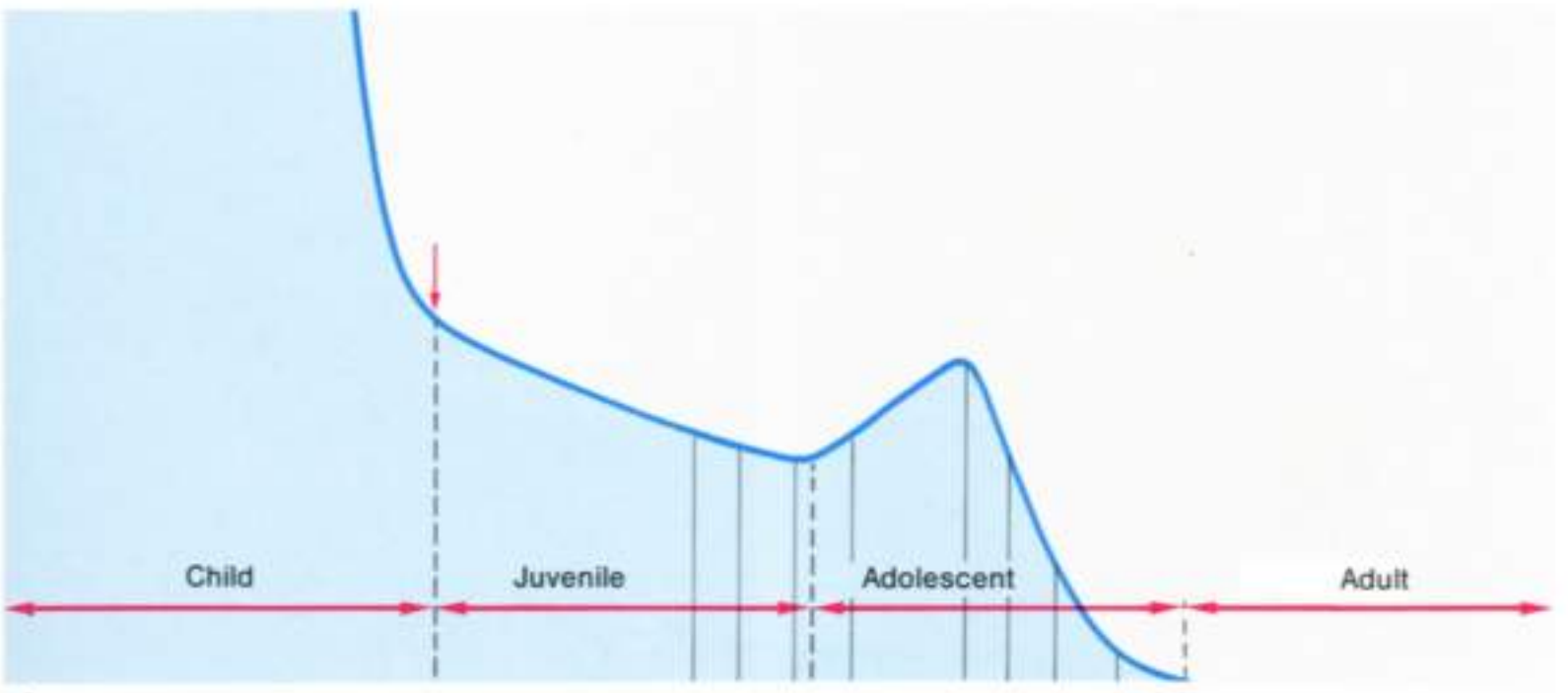
Evaluation of hand radiographs is indicated in the following cases:

- Prior to rapid maxillary expansion
- When maxillomandibular changes are indicated in the treatment of Class III cases, skeletal Class II cases or skeletal open bites
- In patients with marked discrepancy between dental and chronologic age
- Orthodontic patients requiring orthognathic surgery if undertaken between the ages of 16 and 20 years

Growth period									
	1. PP2=	2. MP3=	3. Pisi H1 R=	4. S H2	5. $MP3_{cap}$ R_{cap} $PP1_{cap}$	6. $DP3_u$	7. $PP3_u$	8. $MP3_u$	9. R_u
♂	10.6	12.0	12.6	13.0	14.0	15.0	15.9	15.9	18.5
♀	8.1	8.1	9.6	10.6	11.0	13.0	13.3	13.9	16.0

259 Skeletal age assessment
Correlation table between ossification stages of hand bones and the skeletal age for the period between 8 to 18 years of age. Average values of the patients' ages (in years) are given for boys and girls separately (*Schopf* 1978).

As a rule, girls reach the various developmental stages 2 years earlier than boys.



260 Growth rhythm curve (Björk)
Skeletal age assessment according to Björk, Grave and Brown helps in determining the appropriate period for undertaking dentofacial orthopedic therapy during the maximal puberal growth spurt in adolescents (*Björk* 1972).

Special Clinical Examination

- **Cephalic and facial examination**
- **Soft tissues**
- **Clinical examination of the dentition**

Cephalic and Facial Examination

The shape of the head and the facial structures are assessed; measurements can be evaluated according to the cephalic index of the head (Fig. 261) and the morphologic facial index (Fig. 263).

The form of the facial morphology has a certain relationship to the shape of the dental arch (Figs. 264, 265); however, a direct relationship has not been established.

As a general rule, in borderline crowding cases of a broad facial type, an expansion treatment should be carried out. Extraction therapy should be considered with long face types.

261 Cephalic index
The index is based of the anthropometric determination of the maximum width of the head and the maximum length.

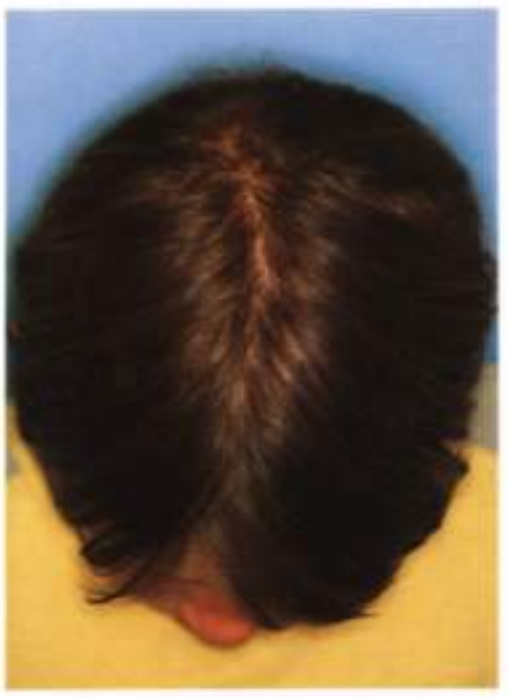
Left: Classification and index values according to *Martin* and *Saller* (1957).

Cephalic Index

$$I = \frac{\text{Maximum skull width}}{\text{Maximum skull length}}$$

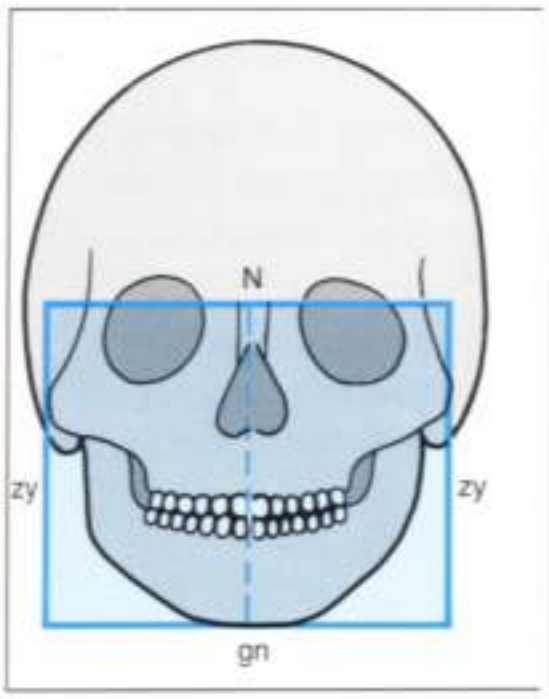
Classification:

• Dolichocephalic (long skull)	x – 75.9
• Mesocephalic	76.0 – 80.9
• Brachycephalic (short skull)	81.0 – 85.4
• Hyperbrachycephalic	85.5 – x



262 Quadrate caput
Characteristic deformity of the skull, a persistent symptom of rickets which occurred when the patient was about 1 year of age.

The square deformity of the skull is caused by the protuberances of the frontal and parietal bones.



Morphologic facial Index

$$I = \frac{\text{Morphologic facial height}}{\text{Bizygomatic width}}$$

Classification:

• Hypereuryprosop	Low facial skeleton	x – 78.9
• Euryprosop		79.0 – 83.9
• Mesoprosop	Average facial skeleton	84.0 – 87.9
• Leptoprosop	High facial skeleton	88.0 – 92.9
Hyperleptoprosop		93.0 – x

263 Morphologic facial index

N = Nasion
zy = Zygoma
gn = Gnathion

Left: The morphological facial heigth is defined as the distance between nasion and gnathion, the bizygomatic width as the distance between the zygoma points.

Right: Classification and index values according to *Martin* and *Saller* (1957).

The facial index has to be taken into account when estimating the Pont Index (p. 208).

264 Broad face

Intra- and extraoral findings in a hypereuryprosopic facial type.

Left: In these patients, the apical base of the jaw is wide in the transverse dimension.

If there is dental crowding in such a case, the inclination of the teeth is confined to the coronal part of the dental arch and is described as coronal crowding.

In these facial types, transverse expansion is indicated.

265 Narrow face

Intra- and extraoral findings in a leptoprosopic type.

Left: Parallel with the reduced development of the bizygomatic width, the apical base is often narrow in transverse direction.

Therefore, in cases of maxillary crowding, not only is there narrowing of the coronal arch, but also in the apical regions.

Examination of the Soft Tissues

Extraoral:	Forehead
	Nose
	Lips
	Chin
Intraoral:	Lip and cheek frenal attachments
	Gingiva
	Palatal and oral mucosa

Forehead

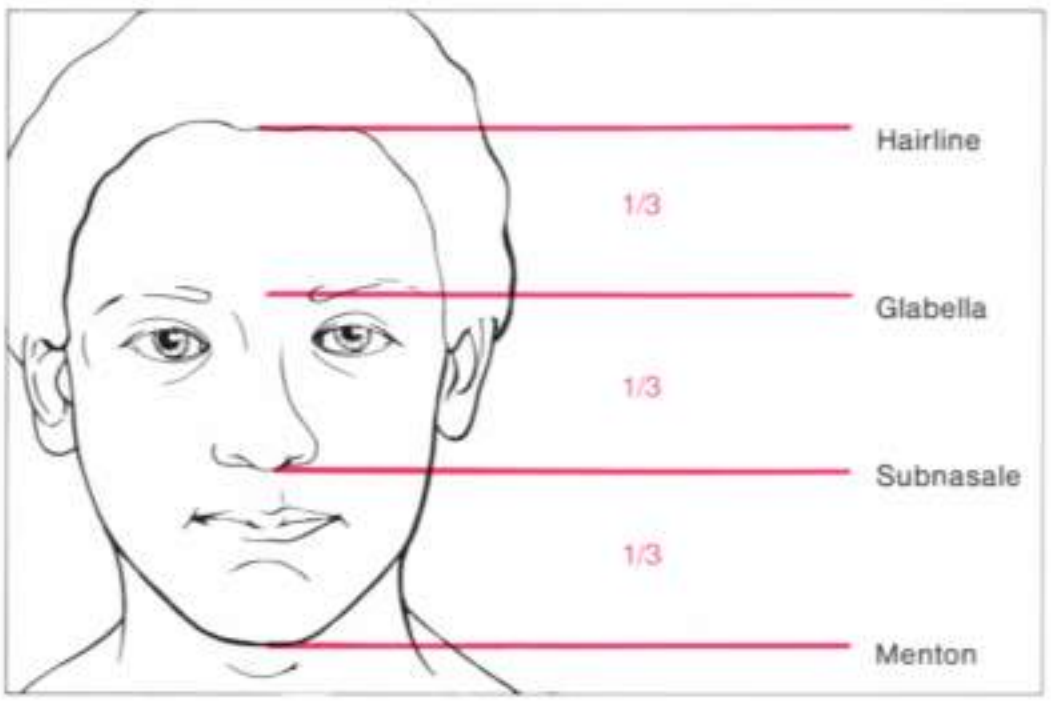
The profile is influenced by the shape of the forehead and the nose and these therefore determine the *esthetic prognosis* of the orthodontic case.

For harmonious facial morphology, the height of the forehead (distance of hairline to the glabella) should be one-third of the entire face height and is therefore as long as the mid-third (distance of glabella to the subnasal line) and the lower third (distance of subnasale to menton).

The *configuration of the forehead* is genetically and ethnically determined and varies according to age and gender. In the frontal view, the forehead is considered in its relationship to the bizygomatic width to describe it as narrow or wide. The lateral forehead contour can be flat, protruding, or oblique. In cases with a steep forehead the dental bases are more prognathic than in cases with a flat forehead (Fig. 267).

266 Height of forehead
The height of the forehead is measured from the hairline to the glabella and normally measures one-third of the total face height (distance hairline to menton).

Right: In the adult it is therefore as high as the middle face height (distance glabella to subnasale) and the height of the lower face (subnasale to menton).



267 Slope of forehead

Left: Flat forehead

Middle: Protruding forehead

Right: Steep forehead

The esthetic appearance of the nasal profile is influenced by the curvature of the forehead. In cases of a steep forehead the dental bases are more prognathic than in cases with a flat forehead.

Nose

Size, shape, and position of the nose determine the esthetic appearance of the face (Figs. 268, 269).

The assessment of the nose in the prognosis of an orthodontic case is therefore of special importance. Before treatment it should be stressed that the nasal profile is not improved by orthodontic procedures and that a rhinoplasty may be necessary later.

The *shape of the nose* is not only determined by hereditary or ethnic factors but may be the result of trauma in childhood (Fig. 269). Besides the contour of the bridge and the tip of the nose (Fig. 268), the size and the shape and width of the nostrils as well as the position of the nasal septum should be assessed. These findings can indicate impairment of nasal breathing (Fig. 270).

268 Size of nose
The vertical nasal length measures one-third of total face height (distance hairline to gnathion).

Left: In the normal case, the relationship between vertical and horizontal length of the nose is 2:1 as viewed from the side.

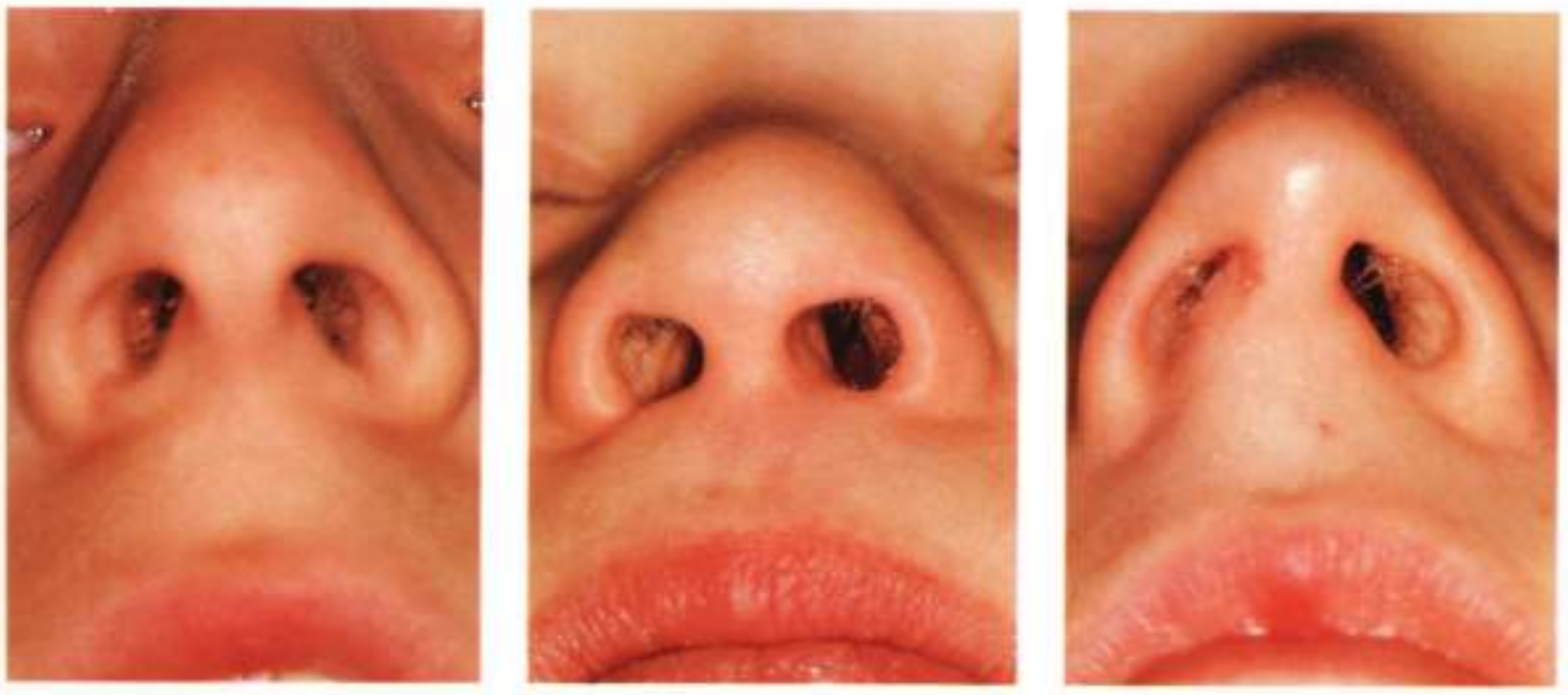
Middle: Microrhinic type with a high root of the nose, short nasal bridge, and an elevated tip.

Right: Patient with a large nasal profile: deep root of the nose, long nasal bridge, and a protruding tip.

269 Nasal contour
Left: Straight nose.

Middle: Convex nasal bridge.

Right: Crooked nose, from previous trauma.



270 Nostrils
The width of the nostrils (alar base) is approximately 70% of the length of the nose (distance nasion to tip of nose).

Left: The nostrils are usually oval and bilaterally symmetrical.

Middle: Nasal breathing is seldom impaired by a slight nasal anomaly with wide nostrils.

Right: Disturbed nasal breathing due to stenosis of the right nostril, combined with a cartilaginous septal deviation.

Lips

Configuration of the lips can be assessed by the following criteria: Lip length, width, and curvature.

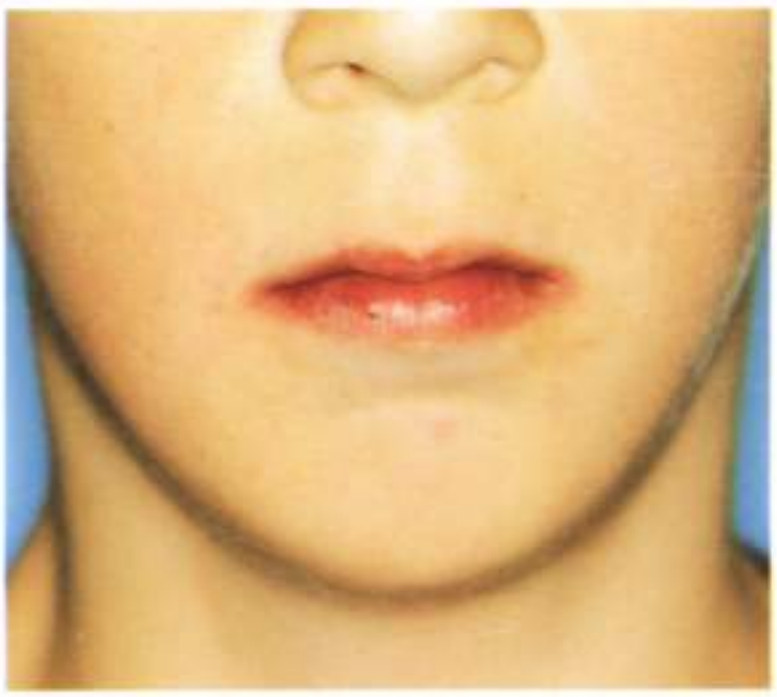
In a blanced situation, the length of the upper lip measures one-third, the lower lip and the chin two-thirds of the lower face height (Fig. 271). In addition, the length of the upper lip should be assessed in relation to the position of the upper incisal edges (Fig. 273).

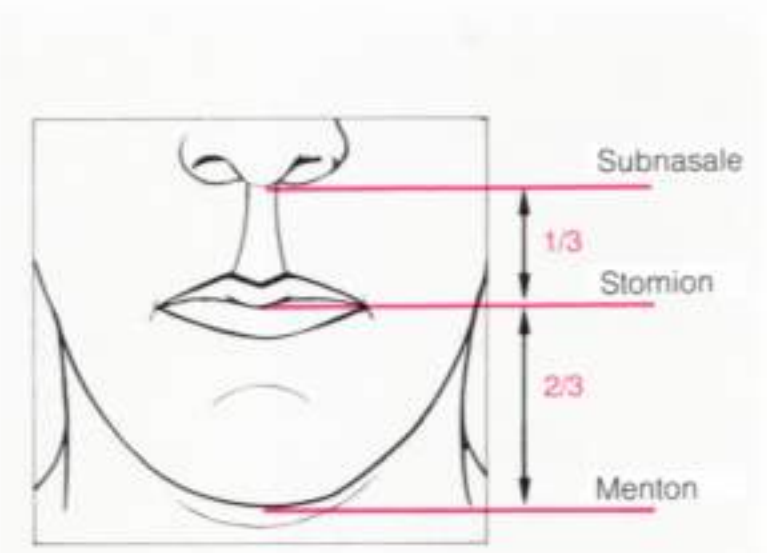
The observation of the nasolabial angle and in particular the mentolabial fold is indicative of the degree of lip tension (Fig. 276, 277).

Apart from ethnic characteristics, lip protrusion is influenced by the thickness of the soft tissues, the tone of the orbicularis oris muscle, position of the anterior teeth, and the configuration of underlying bony structures (Fig. 274).

In patients with lower lip dysfunction, the upper lip is often everted, paler and dry; the lower lip, however, has a better blood circulation and is moist. In some cases, indentations of upper incisal edges are present (Fig. 277).

271 Vertical lip relationship
In a balanced situation, the upper lip length (distance of subnasale to stomion) is one-third and the length of the lower lip and of the chin (distance stomion to menton) is two-thirds of the lower face height.

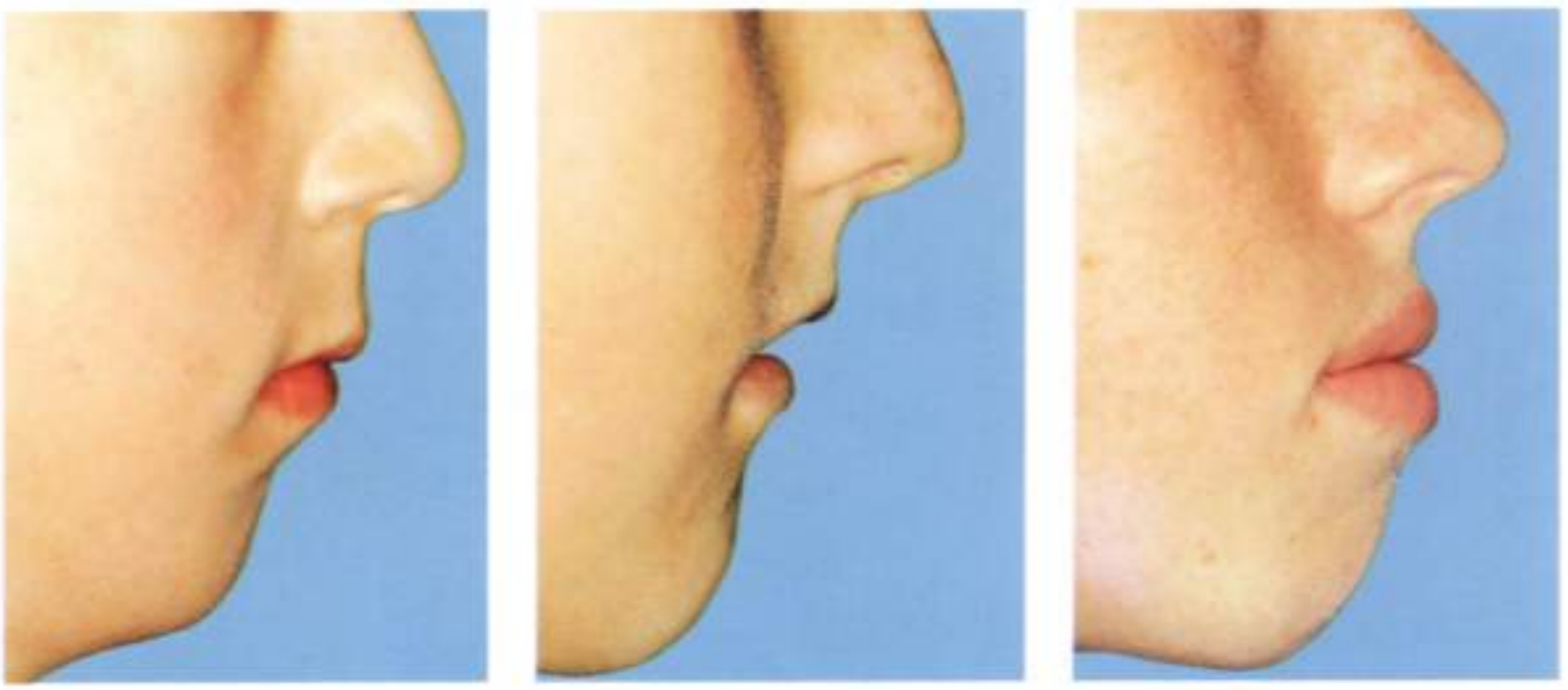




272 Lip morphology
Left: Harmonious lip profile with a narrow mucosal element.

Middle: Short upper lip with narrow mucosal element and disturbed lip seal.

Right: Short cutaneous upper and lower lip with undisturbed lip closure. The lip insufficiency is compensated by eversion of the mucosal part.



273 Relation of upper lip length to front teeth
The upper incisal edges in the rest position and when smiling should show 2 mm in a normal case.

Right: Disharmonious relationship between length of upper lip and incisal edges of upper incisors. The gingiva and the alveolar mucosa are visible in cases of a short upper lip, in conjunction with vertical overdevelopment of the alveolar process (= gummy smile).

Horizontal lip profile

274 Clinical profile
Left: Protrusion of lower lip in relation to upper lip – a symptom of the Class III malocclusion (positive lip step according to *Korkhaus*).

Middle: Normal lip profile. The upper lip protrudes slightly in relation to the lower lip.

Right: Marked retrusion of the lower lip as a symptom of a Class II malocclusion (negative lip step according to *Korkhaus*).

275 Lip step according to Korkhaus
Diagram of different variations of lip profiles, illustrating the lip step.

Left: Positive lip step.

Middle: Slightly negative lip step (normal case).

Right: Marked negative lip step (according to *Korkhaus*).

276 Nasolabial angle
Left: Tense upper lip in maxillary prognathism with anterior proclination of the front teeth.

Middle: These patients usually show characteristic changes in the soft-tissue profile, with reduction of the nasolabial angle (angle between the tangents subnasale – anterior-most point of the columella and subnasale – labrale superius).

Right: Enlarged nasolabial angle as a sign of the retrusive position of the upper lip to the nose.

277 Tense lower lip
Right: Clinical appearance.

Left: Profile radiograph of a tense lower lip.

The marked labial position of the upper anterior teeth in conjunction with the resulting lower lip dysfunction (lower lip sucking) is the cause of this functional disturbance.

Chin

The *configuration of the soft-tissue chin* is not only determined by the bone structure, but also by the thickness and the tone of the mentalis muscle (Fig. 278). Further factors include the morphology and the craniofacial relationship of the mandible.

As well as *chin width*, the development of *chin height* is important from the orthodontic point of view (distance from mentolabial sulcus to menton). Overdevelopment of the chin height alters the position of the lower lip and interferes with lip closure (Fig. 279).

As a rule, the chin contour is assessed in connection with the lower lip position and the configuration of the mentolabial fold, as the profile of these two structures is dependent on the position of the soft-tissue chin (Fig. 280).

The midline of the mandible must be examined in the clinical case of an *asymmetry of the chin* (Figs. 281–283).

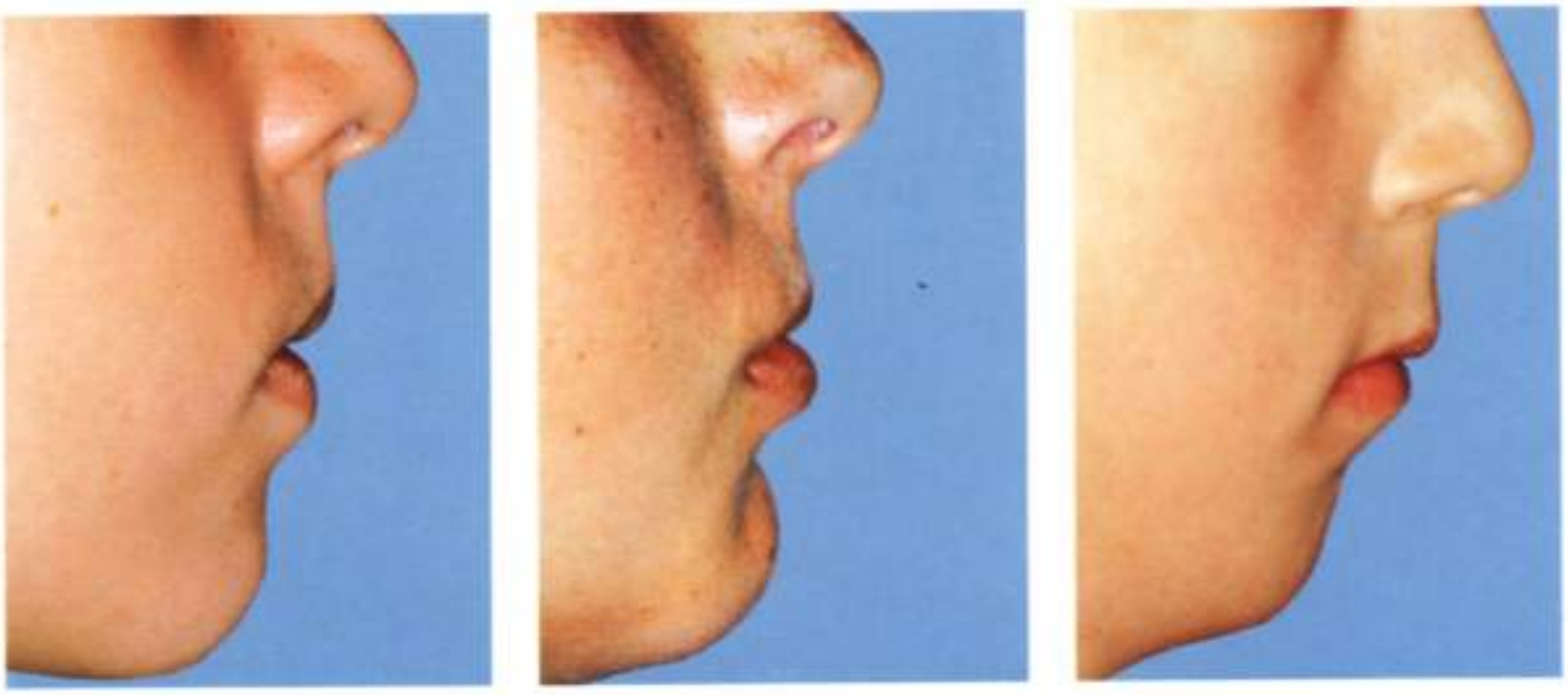
278 Relation of the soft-tissue chin to the bony chin
Frontal and profile picture of a 10-year-old patient with a flat soft-tissue chin.

Middle: The lateral cephalogram shows a distinct positive bony chin contour, compared with the soft-tissue profile. In this case, the skeletal contour is compensated by the thin overlying soft tissue.

279 Overdevelopment of the chin height
Frontal and profile view of a 12-year-old patient with a long lower face and overdeveloped chin height, (distance from mentolabial sulcus menton) causing hyperactivity of the mentalis muscle.

Lip closure is difficult in this type of facial morphology.

In order to improve muscular imbalance, a genioplasty is required or a surgical change of the insertion of the mentalis muscle should be considered.



280 Chin formation and profile contour
The degree of chin formation has a marked influence on the entire profile.

Middle: Protruding chin with a marked mentolabial sulcus, causing a retruded lip profile.

Right: Negative chin formation with absence of the mentolabial sulcus, causing a protruded lip profile.

Asymmetric chin position

281 Frontal view of soft-tissue and skeletal facial configuration

Frontal view of a 26-year-old female patient who shows a displacement of the chin to the left side on clinical examination.

Right: The posteroanterior cephalogram shows that the asymmetry seen on clinical examination is caused by a rotation of the entire mandible to the left – a mandibular laterognathy. (The frontal cephalogram is reversed, so that the asymmetry is in the same direction on both, the facial photograph and the radiograph).

282 Intraoral findings

In occlusion, the midline of the lower dental arch is displaced to the left by the lateral deviation of the mandible.

The molars are in cross-bite on this side.

283 Tomograms of the temporomandibular joints

In conjunction with the mandibular deviation, a marked asymmetry of form and position of the joints is shown.

The right condyle *(left)* is clearly larger than the left *(right)*.

Also the width of the joint space differs between the right and left side.

Tongue

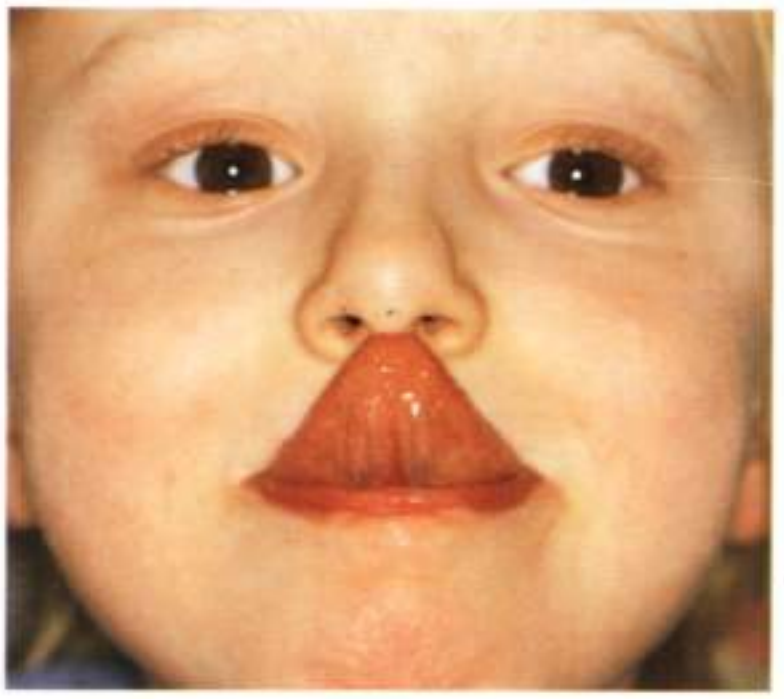
Shape, color, and configuration are assessed at the first clinical examination. The tongue can be small, long, or broad. These findings do not allow conclusions to be drawn about the relative tongue size (Figs. 284, 285). A long, broad tongue does not mean that this is a case of "macroglossia." Changes in the tongue position and mobility are often associated with an abnormal lingual frenum (Fig. 286). A rough assessment of *tongue size* in relation to the size of the oral cavity can be made by studying a lateral cephalometric radiograph (Fig. 284). The diagnosis of a macroglossia requires in each case a more detailed diagnostic investigation (for instance cineradiography), and can only be made after exact analysis of tongue position and mobility, and studying physiological functions (for instance, speaking, swallowing).

Assessment of the character of the mucosa of the tongue is of secondary importance from the orthodontic viewpoint. Functional investigation is the most essential aspect of the clinical examination (see. p. 141).

284 Tongue length
The clinical picture of a long tongue which can reach the tip of the nose.

This single finding does not permit the diagnosis of "macroglossia."

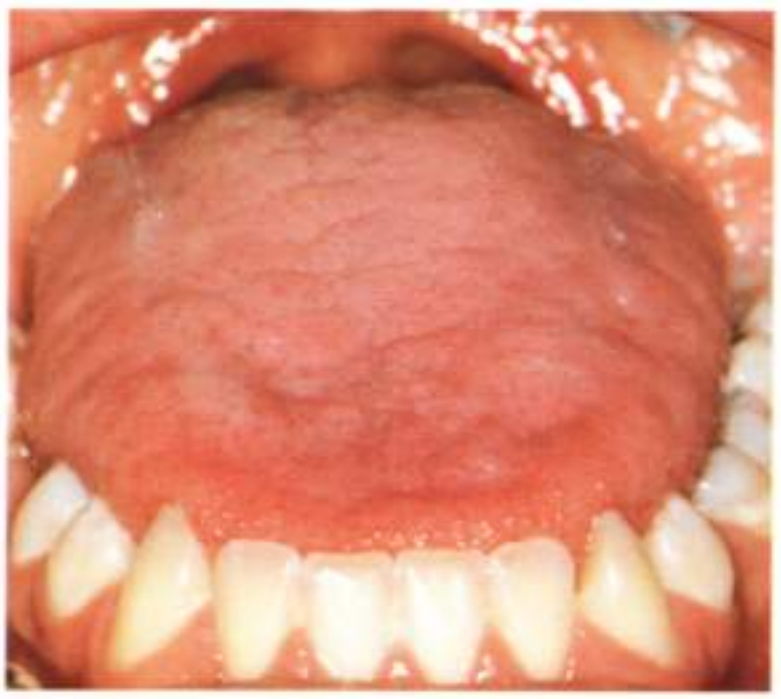
Right: Position of tongue in the lateral cephalogram. The tongue is long but its volume is not too large in relation to the oral cavity.

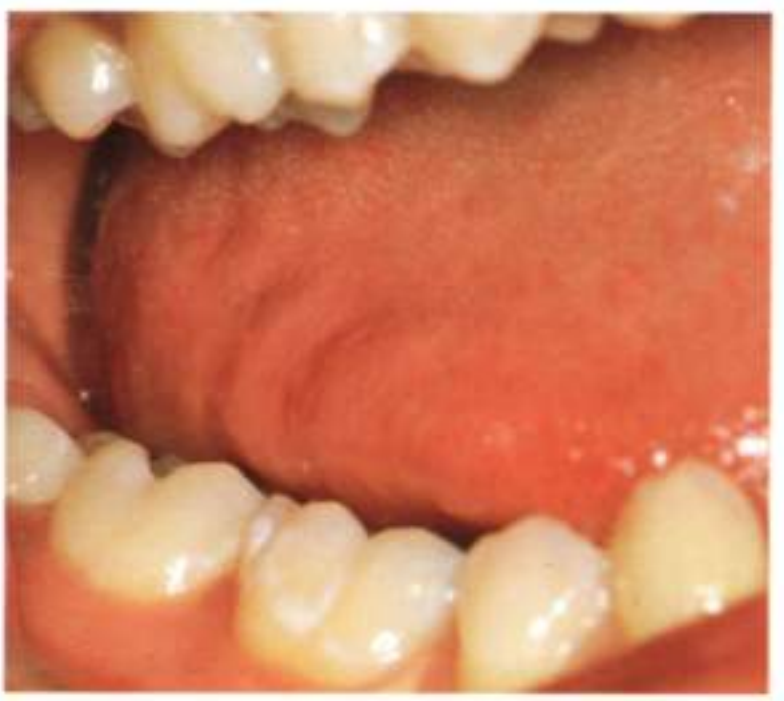


285 Tongue width
Class III case with a broad and low-lying tongue, which extends over the dental arches.

Right: Imprints of the teeth on the lateral margins of the tongue indicate a discrepancy between the width of the dental arch and width of the tongue.

In these cases, the size of the oral cavity should not be decreased further by orthodontic therapeutic procedures (for instance, tooth extractions).





286 Lingual frenum
Left: Intraoral photograph of an attached lingual frenum.

Right: Tongue mobility is impaired by this soft tissue anomaly.

In these cases, the tongue lies low so that impairment of function predisposes to tongue-thrusting.

Lip and Cheek Frena

Among the different frena, the *maxillary labial frenum* in the mixed dentition is of special importance.

A heavy labial frenum may be the cause of a central diastema (Fig. 287). The indication for frenectomy depends on the differential diagnosis. It is only indicated when the attachment is inserted deeply with fiber extensions into the interdental papilla (Fig. 288).

The X-ray film shows a bony fissure between the roots of the upper central incisors as the sign of an interosseous fiber course. Frenectomy, however, should only be done after eruption of the upper lateral incisors.

The *mandibular labial frenum* is less often associated with a median diastema. However, it frequently has a broad insertion which exerts a strong pull on the free and attached gingiva; this can lead to gingival recessions in the lower anterior region already in the mixed dentition stage (Fig. 289).

The presence of buccal attachments must be examined carefully, especially in adolescence and in adults.

Labial frena

287 Deeply inserted labial frenum in the deciduous dentition.
In this 5-year-old female patient, a physiological variant of the maxillary labial frenum attachment exists, a relic of the tectolabial frenum.

At this stage, there is no indication for frenectomy, since in the course of permanent incisor eruption, a spontaneous correction of the diastema can be expected.

288 Deeply inserted labial frenum in the maxilla
Soft tissue morphology in an 8-year-old patient in whom frenectomy is indicated.

Right: If the upper lip is held away and a pull is exerted on the frenum the interdental tissue and the area around the incisive papilla becomes blanched or anemic; the condition of a true diastema exists, caused by interdentally running fibers.

The excision has to dissect out not only the soft tissues but also the interosseous fibers.

289 Anomaly of the mandibular labial frenum
The high insertion of the frenum exerts a strong pull on the attached mucosa of lower anterior teeth and leads to mucogingival lesions. In this morphologic condition, prophylactic, i.e. early periodontal surgery should be carried out.

Right: Atypical formation of the mandibular labial frenum in a young female patient with marked gingival recessions on the lower central incisors.

Gingiva

Examination of the gingiva should include the following criteria:

- Gingival type (thick-fibrous, thin-fragile)
- Gingival inflammation
- Mucogingival lesions

In children the most common form of gingivitis is caused by *plaque accumulation,* and can only be resolved by improving oral hygiene. In other cases of gingivitis, in particular in the adult patient, *periodontal treatment* must be carried out (scaling, curettage, mucogingival surgery) prior to orthodontic treatment. Local gingival lesions may be a symptom of mouth breathing, abnormal occlusal, and functional loadings or of medication (for instance, epilepsy).

Gingivitis and poor oral hygiene are contraindications for orthodontic treatment. Therapy should only be commenced following improved dental and gingival care.

290 Healthy gingiva
Clinical picture of healthy gums, free of inflammation in a 12-year-old female patient at the beginning of orthodontic treatment.

291 Thin-fragile gingival type
Situation in an 8-year-old female patient. The alveolar process is narrow; the roots can be palpated through the mucosa. Gingival recessions develop around the lower central incisors.

Right: The clearly visible vascular pattern of the mucous membrane is characteristic for the thin-fragile gingival type.

A marked tendency exists in this tissue type for producing periodontal damage by labiolingual orthodontic tooth movements.

292 Idiopathic gingival hyperplasia
Young patient with a generalized dense-fibrous gingival hyperplasia which is hereditary.

The abnormal tissue structure hinders dental eruption.

293 Oral hygiene – Gingivitis
In young patients, lack of oral hygiene is the most common cause of this condition.

Oral hygiene can be assessed and explained to the patient by illustrating the plaque using disclosing agents or the UV-lamp and thus motivating the patient.

The plaque score is recorded in the form of an index (*Lange*, 1981, *Rateitschak* et al., 1989).

294 Hyperplastic gingiva
Left: Severe gingivitis in a chronic mouth breather.

Besides poor oral hygiene, the condition is worsened by the dryness of the mouth, caused by the open-lip posture.

Right: Mild fibrous hydantoin hyperplasia in a 12-year-old epileptic girl.

Mucogingival lesions

295 Occlusal trauma
Left: Gingival condition in a 7-year-old girl during the eruption stage of anterior teeth. The upper right central incisor erupts in cross-bite so that the mandibular antagonist is subjected to nonphysiologic occlusal forces.

Right: 1 year later; the lower incisor shows increased mobility and a mucogingival lesion.

296 Lingual recessions
Right: Gingival recessions on the lingual surfaces of lower anterior teeth in a young patient with tongue dyskinesia.

The early damage results from the nonphysiologic tissue loading as a consequence of the dysfunction.

Left: Lateral cephalogram shows clearly the anomalous relation between the tip of the tongue and lower incisors.

(Concretions = deposits caused by *Bacteroides melaninogenicus*).

Palatal Mucosa and Palatal Vault

The *palatal mucosa* is examined as follows: pathologic swelling, ulceration, scar tissue formation.

Pathologic swellings are indicative of displaced tooth germs and cysts (Fig. 297).

Mucosal ulcerations and indentations are characteristic of a traumatic deep bite (Fig. 298). Scar tissue following palatal surgery diminishes the prognosis for development of the maxillary arch (Fig. 299). Changes in the palatal mucosa can also be observed in conjunction with other systemic problems (Fig. 299).

As part of this examination, the size and degree of inflammation of the *tonsils* should be assessed, including an inspection of the *oropharyngeal space.* As there may be possible effects on tongue position and nasal breathing, suspected pathologic findings should be examined by an otolaryngologist (Fig. 370).

297 Mucosal swelling
Abnormal swelling on the palatal aspect of the right anterior maxilla; continuous upper dental arch, with a missing canine.

Right: The X-ray film shows a displaced and impacted canine, as the cause of the swelling.

298 Mucosal indentations
Right: Traumatic deep bite in a Class II, Division 1 case.

Left: A clearly visible groove in the palatal mucosa caused by the lower anterior teeth as the result of the long standing vertical malocclusion.

Besides this finding, there is also gingival dehiscence on the lingual aspect of the central incisors.

299 Palatal mucosa
Left: Scarred palate after surgical closure of an isolated palatal cleft.

Right: Bifid uvula in a 10-year-old girl; mild indication of a familial disposition to cleft lip and palate formation.

Clinical Examination of the Dentition

Clinical examination of the dentition is made in the following sequence:

1) Assessment of the dental status
2) Detailed recording of dental and occlusal anomalies
3) Assessment of the apical bases
4) Determination of the midline of the face and coincidence with dental structures

Orthodontic treatment is contraindicated when *carious teeth* are present. Therapeutic possibilities are limited if severely carious teeth as well as dental structural anomalies are present on account of the reduced enamel resistance (contraindication for fixed appliance treatment).

It is also important to determine the *number of teeth*. In a superficial examination, one often overlooks absent or supernumerary teeth, which are only found later during the course of treatment.

The clinical and radiographic examination should reveal all findings that are not clearly diagnosed on plaster models.

300 Structure of tooth surface
Enamel hypoplasia in a case of severe fluorosis.

The pitted and flat-shaped brownish discolorations in the chalky hypomineralized enamel are characteristic of fluoride-induced changes.

The enamel defect is symmetric on both sides.

301 Dental deposits
Mixed dentition with hard black deposits which encircle and lie parallel to the neck of the teeth, particularly on deciduous teeth.

The black-brown deposits are caused by *Bacteroides melaninogenicus*. Dentitions with such recurrent accumulations show great resistance to caries. There is a physiologic recession of these changes in puberty.

302 Wear facets
Bilateral buccal nonocclusion with marked wear facets on the lingual cusps of upper premolars.

In our patients, occlusal abrasions are often the result of attrition and indicative of parafunctional mandibular movements.

Clinical Examination – Record Sheet

1) General Findings

State of development: age related / overdeveloped / underdeveloped
mentally normal / early / late developer
lively / quiet / nervous / phlegmatic
easy / difficult to educate

Body height: cm
Weight: kg
Stature: strong / tall / average / short / adipose
Dental age: years
Nutritional state: good / bad
Skeletal age: years

2) Extraoral Findings

Head form: narrow / broad / long / short
Facial form: small / broad / round / angular / oval / triangular
Facial asymmetry:
Scars:
Shift of maxillary midline relative to the facial midline: yes / no right / left mm

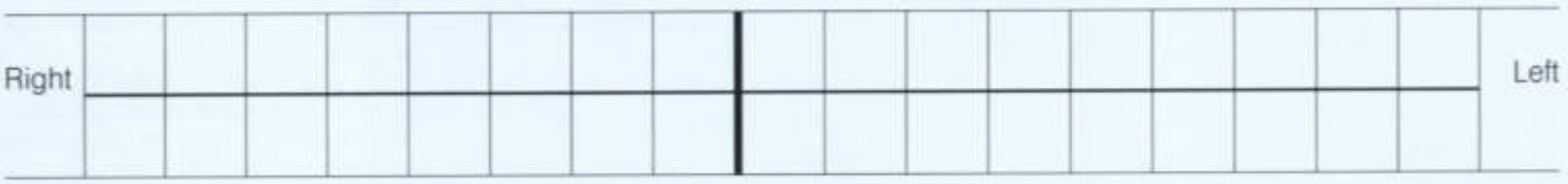
Lip form:
Lips: normal / dry / fissured / scarred / indentations / after surgery
Lip posture: competent / incompetent / everted
Lip step: positive / negative / straight

Chin form:
Mandibular angle: normal / increased / decreased
Nose form:
Nasal bridge:
Nostrils (alar width):
Forehead height:
Curvature:

3) Intraoral Findings

A) *Dental findings*

General impression of oral hygiene: good / poor / moderate
Caries susceptibility: none / moderate / severe



c = caries
z = tooth not to be maintained
x = tooth extracted
m = tooth malformation
a = nonvital tooth
F = large filling
W = wear facet
(= narrowed space
D = discoloration
Fractured tooth:
Dental treatment:

B) *Examination of the oral cavity*

Maxillary labial frenum: strong / weak / deep insertion / frenectomized
Mandibular labial frenum: strong / weak / deep insertion / frenectomized
Buccal frenum: normal / pathologic
Vestibuloplastic: yes / no
Gingiva: normal / inflamed / hyperplastic
Recessions:
Indentations:
Periodontal disease: yes / no
Periodontal chart from:
Oral mucosa: normal / pathologic changes
Palatal mucosa: normal / pathologic / surgery / swellings
Tongue size:
Tongue frenum:

Apical base in the sagittal direction:
Maxilla: normal / large / small
Mandible: normal / large / small
Apical base in the transverse direction:
Maxilla: normal / large / small
Mandible: normal / large / small
Palate: high / average / flat

Functional Analysis

Modern orthodontics is not only restricted to static evaluation of the teeth and their supporting structures, but also includes all functional units of the masticatory system (according to Eschler, 1952), i.e. the stomatognathic system. Therefore, nowadays, functional analysis constitutes a considerable part of the clinical examination. It is not only significant for the etiologic evaluation of the malocclusion but also for determining the type of orthodontic treatment indicated. The three most important aspects of orthodontic functional analysis are:

- **Examination of the postural rest position and maximum intercuspation**
- **Examination of the temporomandibular joint**
- **Examination of orofacial dysfunctions**

Examination of the Relationship: Postural Rest Position – Habitual Occlusion

- Determination of the postural rest position
- Registration of the postural rest position
- Evaluation of the relationship: postural rest position – habitual occlusion, in three planes of space

When the mandible is in its rest position, the synergists and antagonists of the orofacial system are in their basic tonus and are balanced dynamically. This position of the mandible results from the reaction to the force of gravity. It can also be affected, in the short-term, by other influences (e.g. fatigue, stress, anxiety). As the rest position changes according to, among other things, the head posture, the rest position must be examined under standardized conditions.

The rest position should be determined with the patient relaxed and sitting upright. The head is oriented by having the patient look straight ahead (habitual position). If this seems too variable, then the head can be positioned with the Frankfurt horizontal parallel to the floor (see p. 173 for definition).

Determination of the Postural Rest Position

In order to determine the postural rest, the patient's orofacial musculature must be relaxed. Muscle exercises (e.g. "tapping test") can be used to help relax the musculature prior to carrying out the actual examination. When using the "tapping test" the patient is told to relax and the clinician opens and closes the mandible passively and with constantly increasing frequency. Should the patient be very tense, the musculature can be relaxed with mild electric impulses (e.g. Myomonitor®).

When the mandible is in the postural resting position, it is usually 2–3 mm below and behind the centric occlusion (recorded in the canine area).

The space between the teeth, when the mandible is at rest, is referred to as the freeway space or interocclusal clearance. Several methods can be used to determine the rest position during the clinical examination (p. 124).

- Phonetic method
- Command method
- Non-command method
- Combined methods

Phonetic method. The patient is told to pronounce certain consonants or words repetitively (e.g. "M", "Mississippi"). The mandible returns to the postural resting position 1–2 seconds after the exercise.

Command method. The patient is "commanded" to perform selected functions (e.g. swallowing), after which the mandible spontaneously returns to the rest position. In the strictest sense, the phonetic exercise can also be considered one of the command methods.

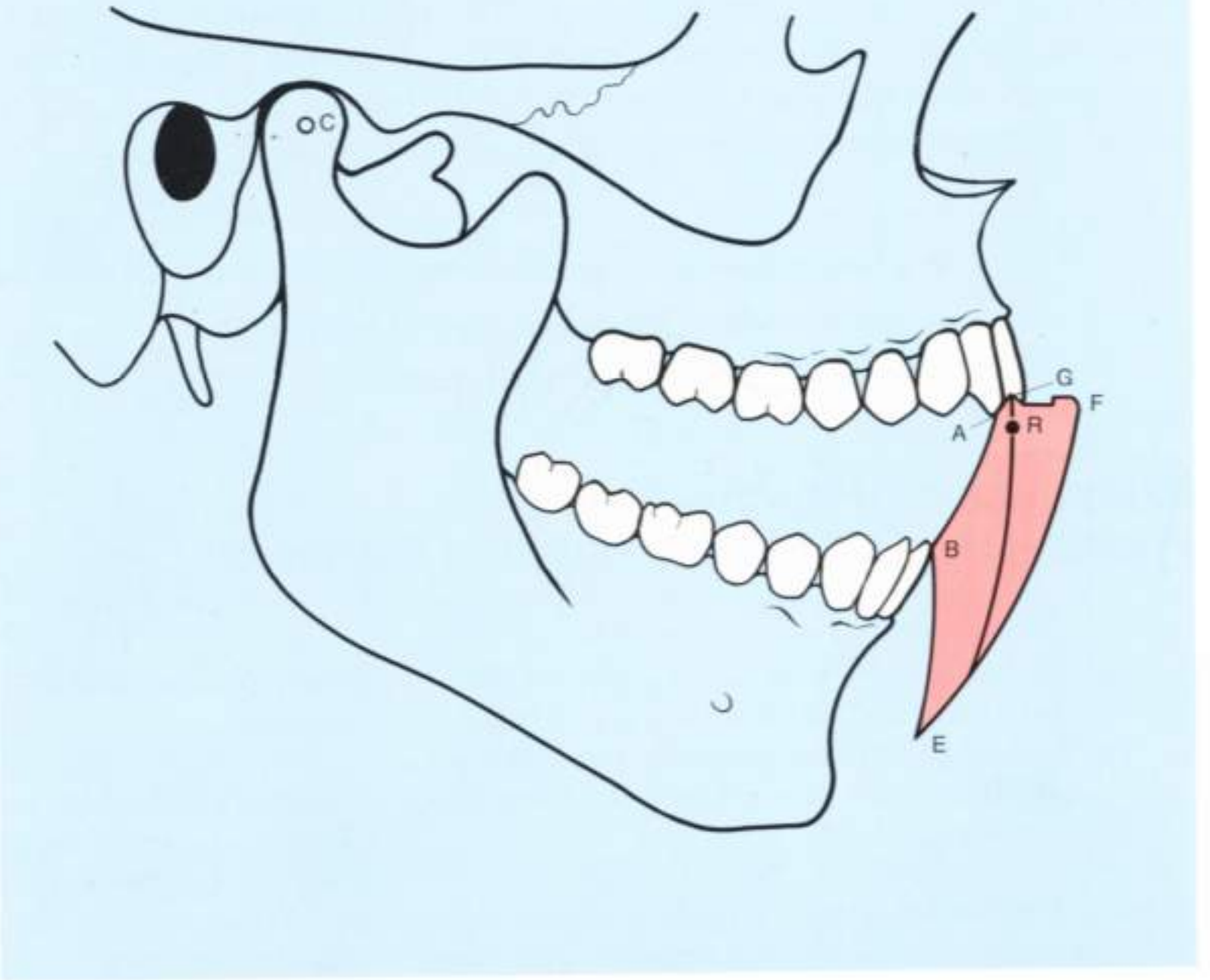
Non-command method. The patient is distracted (e.g. the clinician talks to the patient) so as not to perceive which type of examination is being carried out. While being distracted, the patient relaxes, causing the musculature to relax as well, and the mandible reverts to the postural rest position.

303 Border movements of the mandible – sagittal plane

Projecting the movements of the mandible through the facial midline, along the vertical and sagittal planes, results in a characteristic pattern (Posselt diagram, schematic illustration):

A = Retruded contact position
A–B = Hinge axis movement
B = Transition from hinge axis movement to posterior opening movement
C = Axis of rotation of the condyle when opening the mandible from the rest position
E = Maximum jaw opening
F = Protruded contact position
G = Habitual intercuspation
R = Mandibular rest position

The location of the rest position in this schematic illustration of border envelope of mandibular motion is variable. Usually, the postural rest position of the mandible is 2–3 mm posteroinferiorly to centric occlusion (according to *Ramfjord* and *Ash*, 1968).



304 Influences determining intraindividual and interindividual variations in the rest position

Overview of the clinically relevant factors affecting the peripheral and central control mechanisms of the postural muscle tone, either long-term or short-term.

Components affecting the rest position

Short-term influences:	Long-term influences:
• Inconsistency in muscle tonicity • Respiration • Body posture • Stress situations • Dysfunction of the temporomandibular joint	• Attrition of the dentition • Premature loss of teeth • Diseases of the neuromuscular system

Combined methods. These methods of determining the rest position are the most suitable for functional analysis in children. The patient is first observed during swallowing and speaking. In the case of older children, the "tapping test" is carried out in order to relax the musculature. The patient is then distracted, similarly to when using the non-command method.

Regardless of the clinical method in use, the mandible must be checked extraorally to ensure that it actually has assumed the rest position. In order to do so, palpate the submental region: relaxed muscles in this area indicate that the rest position has been attained.

The lips are then carefully parted with the thumb and forefinger – ensuring that the line of lip contact is not opened completely – to observe the maxillomandibular relationships in the rest position.

305 Head posture for determining the rest position
The physiologic rest position of the mandible is dependent on the head posture. Therefore, clinical registration must be carried out under standardized conditions.

The rest position should be determined with the patient completely relaxed, sitting upright and looking straight ahead.

306 Manual guidance of the mandible while carrying out the "tapping test"
The chin is placed between the thumb and the forefinger. The clinician uses this grip to carry out passive opening and closing movements of the mandible in rapid succession in order to relax the masticatory muscles prior to determining the rest position. Verify whether the musculature has been relaxed by palpating the submental muscles.

307 Rest position speculum
Determination of the mandibular rest position using the rest position speculum, according to *A. M. Schwarz*. The instrument is placed laterally between the lips in order to observe the functional jaw relationship.

Clinical experience has shown the determination of the physiologic rest position to be difficult using the speculum, as this instrument interferes with the lip seal and the entire reflex mechanism of the resting tonus.

Registration of the Rest Position

Registration of the mandibular rest position is important in those orthodontic cases where the functional analysis is significant for treatment planning. There are various techniques of registration. The two most commonly used methods originate from the field of prosthodontics and include the intraoral indirect method (registration with impression material) and the extraoral direct method (registration by means of skin reference points). The *extraoral indirect methods* are the most reliable:

- Roentgenocephalometric registration
- Kinesiographic registration

Roentgenocephalometric registration. Two cephalograms are required, either in lateral or frontal projection, depending on how the question is formulated:
- one radiograph in centric (habitual) occlusion
- and one with the mandible in its rest position.

Roentgenocephalometric registration of the rest position

308 Functional physiologic rest position
Left: Cephalogram in centric occlusion.

Right: In postural resting position.

The rest position is 3 mm below and posterior to the centric occlusion, i.e. the mandible is moved from the rest position to centric occlusion by a rotational action only.

The advantage of this type of roentgenographic technique is that, unlike other methods, the physiologic reflex mechanism and the line of contact of the lips are not disturbed while taking the registration.

309 Rest position in Class II malocclusion with the mandible forced posteriorly
Left: Cephalogram in habitual occlusion.

Right: Radiograph in rest position.

When compared to habitual occlusion, the rest position of the mandible is further anteriorly. This finding implies that the mandible is sliding toward the posterior due to occlusal interference during the articular phase of the closing movement from postural rest to full occlusion.

Should the mandible be guided into a functional malocclusion – as with this female patient – a third radiograph should be taken with the teeth in their initial premature contact position.

The rest position and freeway space can be determined by comparing the radiographs.

Kinesiographic registration. The mandibular kinesiograph, according to Jankelson (1984), allows the mandibular rest position to be registered three-dimensionally. The position of the mandible is recorded electronically by:

- a permanent magnet, which is fixed with rapid-setting acrylic to the lower anterior teeth, and
- a sensor system of six magnetometers mounted on spectacle frames.

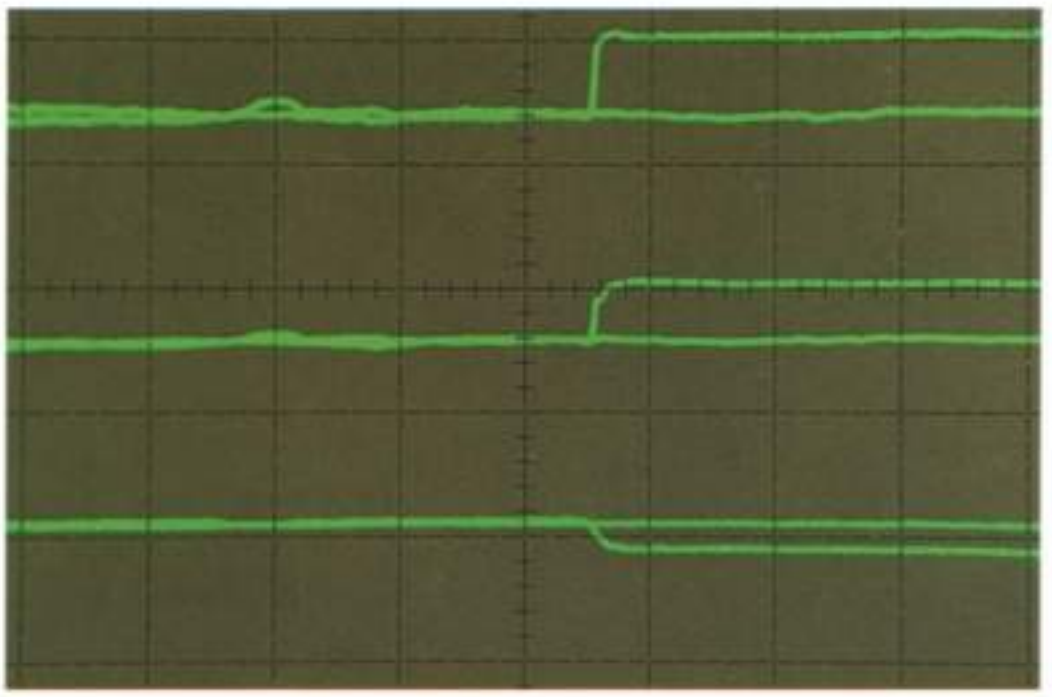
Every movement of the mandible and the attached magnet out of centric occlusion, alters the strength of the magnetic field. These changes are recorded by the sensors, processed in the kinesiograph and displayed on a storage oscilloscope.

The mandibular movements and rest position are recorded two-dimensionally on two preselectable levels. The electronic circuitry also allows the rest position to be recorded as three-dimensional coordinates.

Kinesiographic registration of the rest position

310 The recording unit
The spectacle frame of the mandibular kinesiograph, according to *Jankelson*, is aligned on the patient. The lightweight aluminum frame supports a sensor system which registers the three-dimensional spatial changes of the magnet during excursions of the mandible.

Left: The permanent magnet fixed into place (Model K-5-R, Myo-Tronics Research Inc. Seattle, Washington, USA).

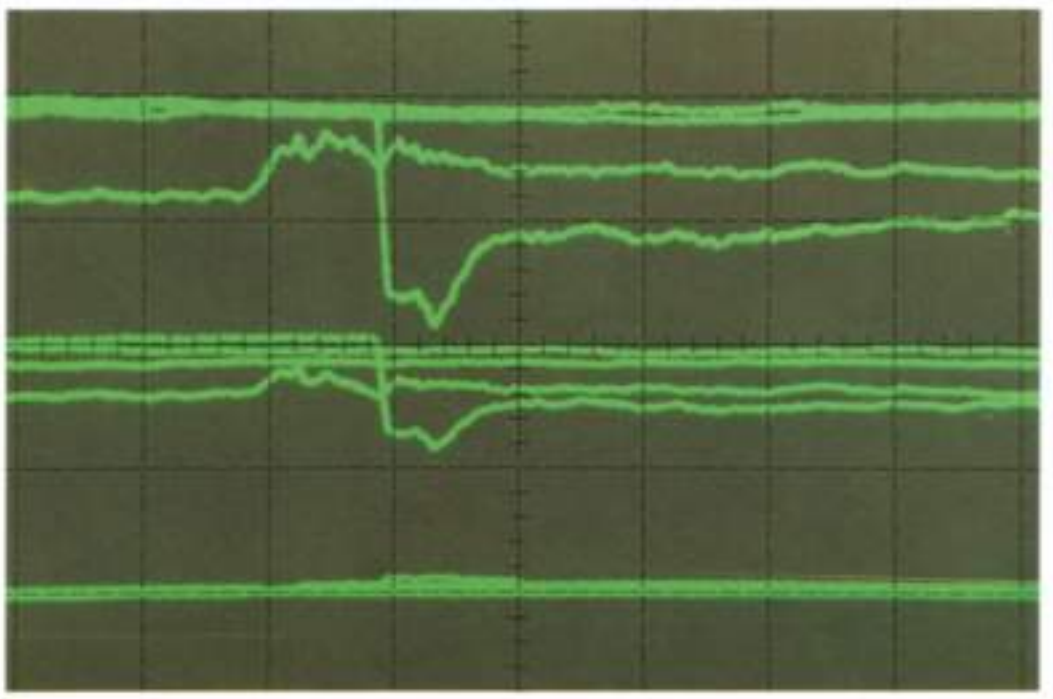


311 Stable rest position

Top line: Vertical plane.
Center line: Sagittal plane.
Bottom line: Horizontal plane.

Downward deviations of the line indicate inferior, posterior and left lateral movements of the mandible, depending on the dimension.

Stable mandibular rest position. When moving from the rest position to the occlusal position, the mandible moves upward and forward and deviates toward the left. The freeway space is small (1 graduation on the scale = 2 mm).



312 Unstable rest position
When compared to Fig. 311, the lines fluctuate considerably over several recordings (same patient as in Fig. 311).

This is an example of incorrect registration of the rest position. In this case, the rest position of the mandible was determined, based on the centric occlusion. The rest position cannot be determined correctly using this technique. The relationship between postural rest and centric (habitual) occlusion must always be registered starting from the rest position of the mandible.

Evaluation of the Relationship between Rest Position and Habitual Occlusion

The movement of the mandible from the rest position to full articulation is analyzed three-dimensionally: In the sagittal, vertical, and frontal planes.

The closing movement of the mandible can be divided into two phases:

- *Free phase:* Mandibular path from the postural rest to the initial or premature contact position.
- *Articular phase:* Mandibular path from the initial contact position to centric or habitual occlusion. In case of functional equilibrium, the articular phase does not occur (movement without tooth contact).

When closing from the rest position, the mandible may undergo both rotational and sliding movement. The objective of this analysis is to determine the amount and direction of movement as well as the proportions of the rotational and sliding components. The following movements of the mandible from the rest position to habitual occlusion must be differentiated for orthodontic diagnosis:

- Pure rotational movement (hinge movement)
- Rotational movement with an anterior sliding component
- Rotational movement with a posterior sliding component

Evaluation in the Sagittal Plane

When evaluating the relationship of the rest position to the habitual occlusion in the sagittal plane, the exceptional features of the Class II and Class III malocclusions are analyzed.

Metric analysis of the relationship between rest position and habitual occlusion – case example –

313 Cephalometric registration of the rest position
Left: Lateral cephalogram with the mandible in its rest position.

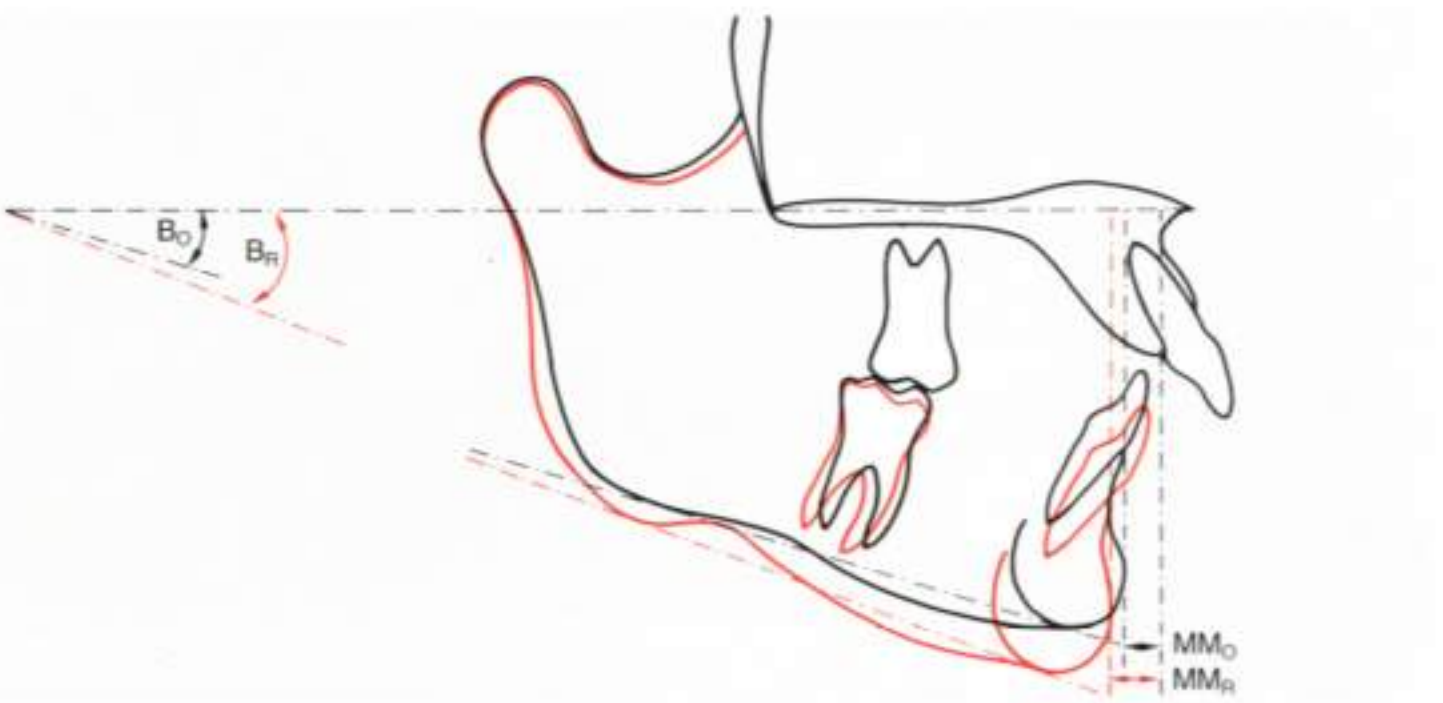
Right: Radiograph taken in habitual occlusion.

The rotational and sliding movement components from the rest position to occlusion can be recorded metrically by correlative analysis of these two radiographs. In the case of this skeletal Class II malocclusion, the rotational component is 5° and the anterior sliding component 2.4 mm.

The evaluation technique is shown in Fig. 314.

314 Method of evaluation
B_O = Basal plane angle (B ∢) in occlusion.
B_R = The same angle, when the mandible is in its rest position.
MM_O = Distance between two perpendiculars drawn to the base line of the maxilla, which pass through the pogonion and "A" point and are extended inferiorly.
MM_R = The same relationship in the rest position.

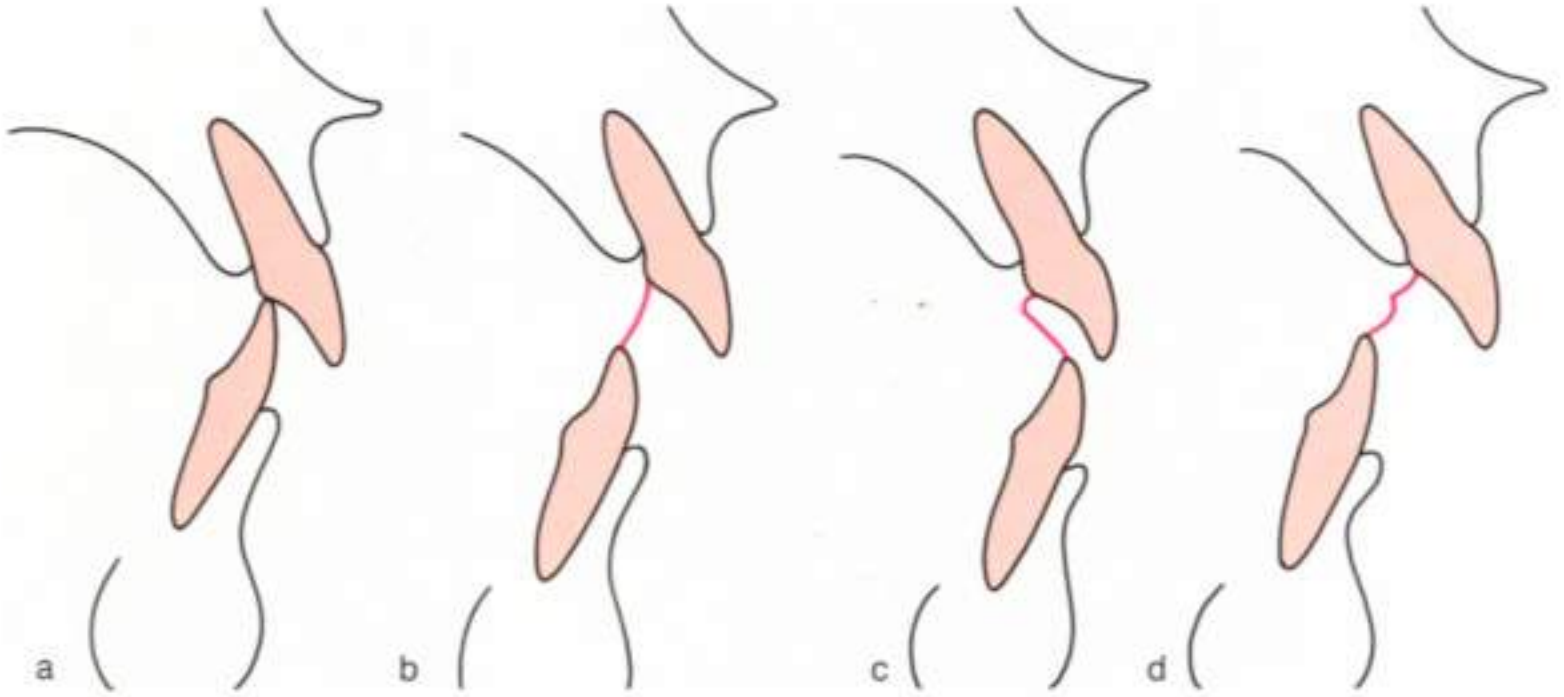
The difference between the angles B_O and B_R reveals the rotational component. The difference between MM_O and MM_R indicates the sliding component.



Class II Malocclusions

Due to the different types of movement of the mandible from the rest position to occlusion, the Class II malocclusions can be divided into three functional types:

- Rotational movement *without a sliding component*
  The neuromuscular and morphologic relationships correspond to each other. There is no functional disturbance (functional true Class II malocclusion) (Fig. 316).
- Rotational movement *with posterior sliding movement*
  The mandible slides backwards and is guided into a posterior occlusal position. This finding reveals a functional Class II malocclusion and not a true Class II malrelationship (Fig. 317).
- Rotational movement *with anterior sliding movement*
  Starting from the relatively posterior rest position the mandible slides forwards into habitual occlusion. The Class II malocclusion is actually more pronounced than can be seen in habitual occlusion.



315 Functional classification of Class II malocclusions according to the relationship between rest position and full occlusion in the sagittal plane

Red = Mandibular path from the rest position to full occlusion

a Maximum articulation
b Pure rotational movement of the mandible from postural rest to habitual occlusion.
c Closing movement of the mandible, with posterior sliding action.
d Closing movement of the mandible, with anterior sliding action.

316 Class II malocclusion, without sliding action
Left: Habitual centric position.
Right: Rest position of the mandible.

Functional true Class II malocclusion whereby the mandible moves from the rest position to habitual occlusion by means of rotational movement without severe sliding action. The mandible closes as shown in Fig. 315b.

317 Class II malocclusion with posterior sliding action
When moving from the rest position (right) to habitual occlusion, the mandible performs a rotational movement as well as a posterior sliding action. The mandible closes as shown in Fig. 315c.

The functional relationships correspond to those of a Class I relationship. When in habitual occlusion, the mandible is forced posteriorly. The prognosis for correction of the mandibular displacement is very favorable in such cases.

Class III Malocclusions

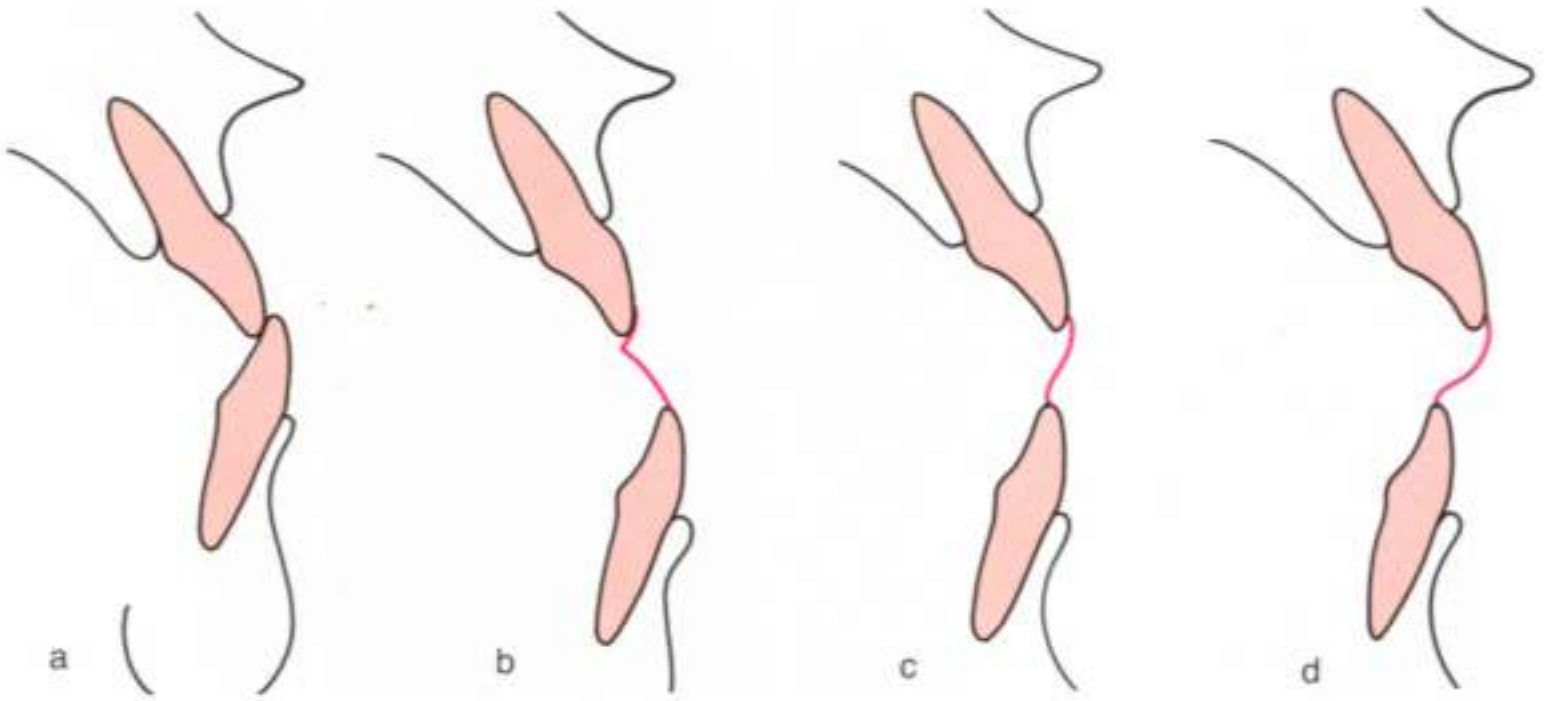
The functional relationships of Class III cases determine the orthodontic treatment possibilities and the prognosis of the malocclusion. The closing path of the mandible from the rest position can be divided into three types (Fig. 318):

- Rotational movement without sliding action
  The anatomic/morphologic relationships correspond to the functional relationships (non-functional, true Class III malocclusion – unfavorable prognosis).
- Rotational movement with anterior sliding action
  During the articular phase, the mandible shifts forwards and into a prognathic, forced bite (functional, non-skeletal malocclusion, so-called pseudo-Class III – favorable prognosis) (Figs. 319, 320).
- Rotational movement with posterior sliding action
  In cases with pronounced mandibular prognathism, the mandible may slide posteriorly into the position of maximum intercuspation. This masks the true sagittal dysplasia.

318 Functional classification of Class III malocclusions according to the relationship between rest position and full occlusion in the sagittal plane

Red = Mandibular path from the rest position to full occlusion.

a Maximum articulation.
b Closing movement of the mandible, with posterior sliding action.
c Pure rotational movement of the mandible from postural rest to occlusal position.
d Closing movement of the mandible, with anterior sliding action.



Functional Class III malocclusion
– case example –

319 Occlusion
Class III malocclusion in the early stages of the mixed dentition.

The deciduous canines show a cross-bite relationship, are elongated, and their tips not abraded.

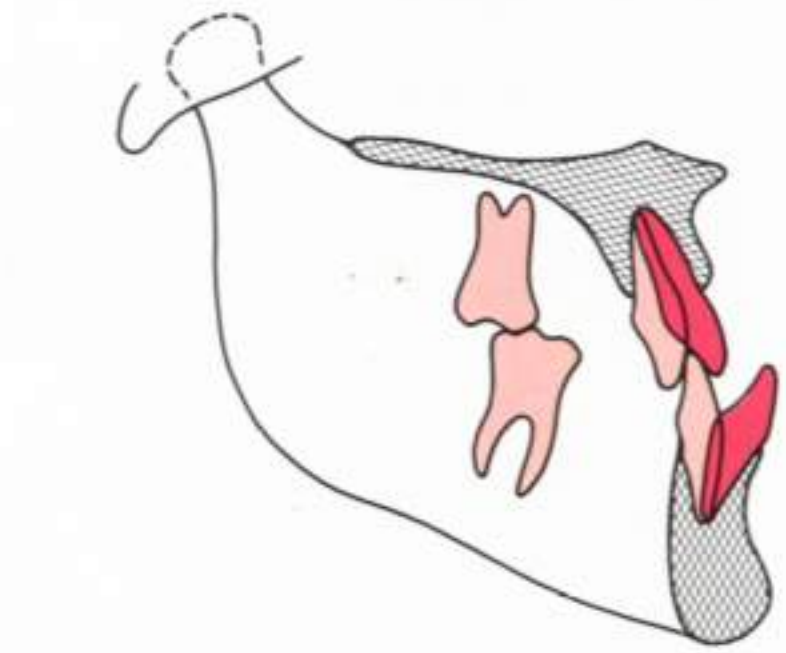
320 Relationship between postural rest and habitual occlusion
Left: Rest position.
Center: Initial tooth contact.
Right: Habitual occlusion.

Moving from the rest position the mandible slides forwards in the articular closing phase due to premature contact of the deciduous canines (refer to Fig. 318d). Although the prognosis for the treatment of functional Class III malocclusions is favorable, the combination with an open bite, as in this case, is unfavorable.

Mandibular Prognathism
True Forced Bite – Pseudo-Forced Bite

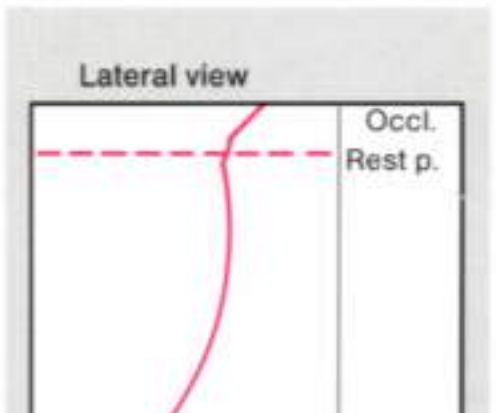
In cases of mesioclusion, an anterior sliding action is not always a symptom of a functional Class III malocclusion. With this functional diagnosis, the "true forced bite", with its favorable prognosis, and the "pseudo-forced bite", with its unfavorable prognosis, must be differentiated as far as cephalometrics is concerned.

The term *"pseudo-forced bite"* includes those true skeletal Class III malocclusions where, due to partial dentoalveolar compensation of the skeletal dysplasia in the anterior region (labial tipping of the upper and lingual tipping of the lower incisors), the mandible occludes at the end of the closing path by means of an anterior sliding action. If one reconstructs the tipping of the anterior teeth in a pseudo-forced bite, these cases have a pronounced negative overjet. The dentoalveolar compensation of the skeletal dysplasia, which already exists when treatment is started, greatly restricts the range of orthodontic treatment possibilities and unlike a true forced bite, is indicative of a very unfavorable prognosis.



321 Dentoaveolar-compensated Class III
In cases with partially dentoalveolar-compensated skeletal Class III relationship, where the upper incisors are tipped labially and the lower incisors tipped lingually, the mandible may be guided toward the anterior while closing. However, placing the incisors in the correct axial position reveals a pronounced negative overjet which eliminates the anterior sliding component.

Left: Cephalogram of a patient with partially dentoalveolar-compensated mandibular prognathism.



Pseudo-forced bite

322 Occlusion
Habitual occlusal position of a Class III dysplasia with linguoversion of the lower incisors and labioversion of the upper incisors as well as a pseudo-forced bite (refer to Fig. 321, left).

Left: Graphic registration of the sagittal closing movement in this female patient. The mandible slides toward the anterior during the articular phase.

323 Relationship between postural rest and habitual occlusion
Left: Rest position.
Center: Initial tooth contact.
Right: Habitual occlusion.

After the mandible has left its rest position, the incisal guidance of the upper labially and lower lingually inclined incisors forces it to slide towards the anterior during the final stages of the closing action.

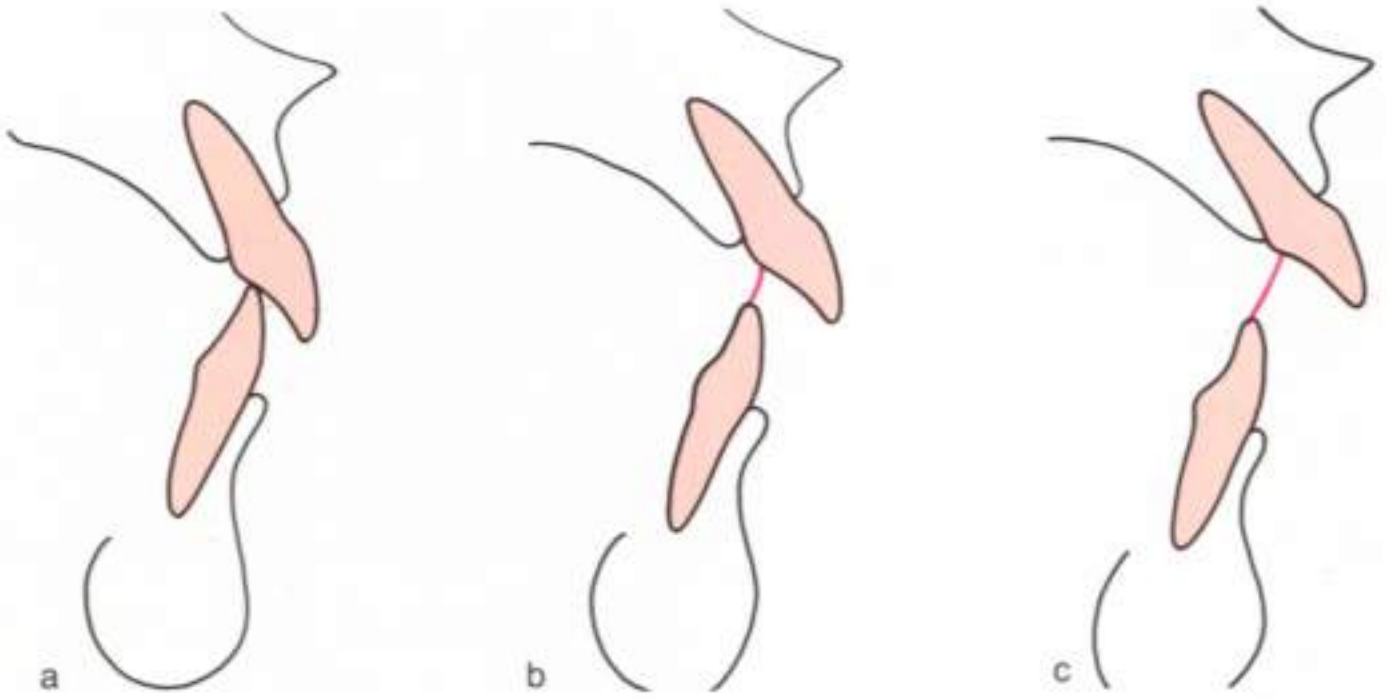
The joint analysis of the incisor positioning and the functional deviation leads to the diagnosis of a pseudo-forced bite.

Evaluation of the Relationship between Rest Position and Habitual Occlusion in the Vertical Plane

The vertical dimension of the freeway space is assessed. This analysis is of particular importance to cases with a deep overbite. According to Hotz and Mühlemann (1952) one should differentiate between two types: true deep overbites and pseudo-deep overbites (Fig. 324).

The *true deep overbite* with a large freeway space, is caused by infraclusion of the molars. The prognosis for successful therapy with functional methods is favorable. As the interocclusal clearance is large, sufficient freeway space will remain after extrusion of the molars.

The *pseudo-deep overbite* has a small freeway space. The molars have erupted fully. The deep overbite is caused by overeruption of the incisors. The prognosis for elevating the bite using functional appliances is unfavorable. If the freeway space is small, extrusion of the molars adversely affects the rest position and may create TMJ problems or cause a relapse of the deep overbite.



324 Functional classification of deep overbite
a Occlusal position
b Pseudo-deep overbite with small freeway space.
c True deep overbite with large freeway space.

Schematic illustration of the two functional types of deep overbite, according to *Hotz* and *Mühlemann* (1952).

The physiologic freeway space, recorded in the canine region, is approximately 4 mm in children and 2–3 mm in adults.

325 Pseudo-deep overbite
Left: Habitual occlusion.

Right: Rest position of the mandible.

Class II malocclusion with small freeway space in the postural position.

The deep overbite is combined with overeruption of the lower incisors.

Pseudo-deep overbite cases are difficult to treat as this type of malocclusion cannot be corrected by extrusion of the molars.

326 True deep overbite
Left: Habitual occlusion.

Right: Rest position of the mandible.

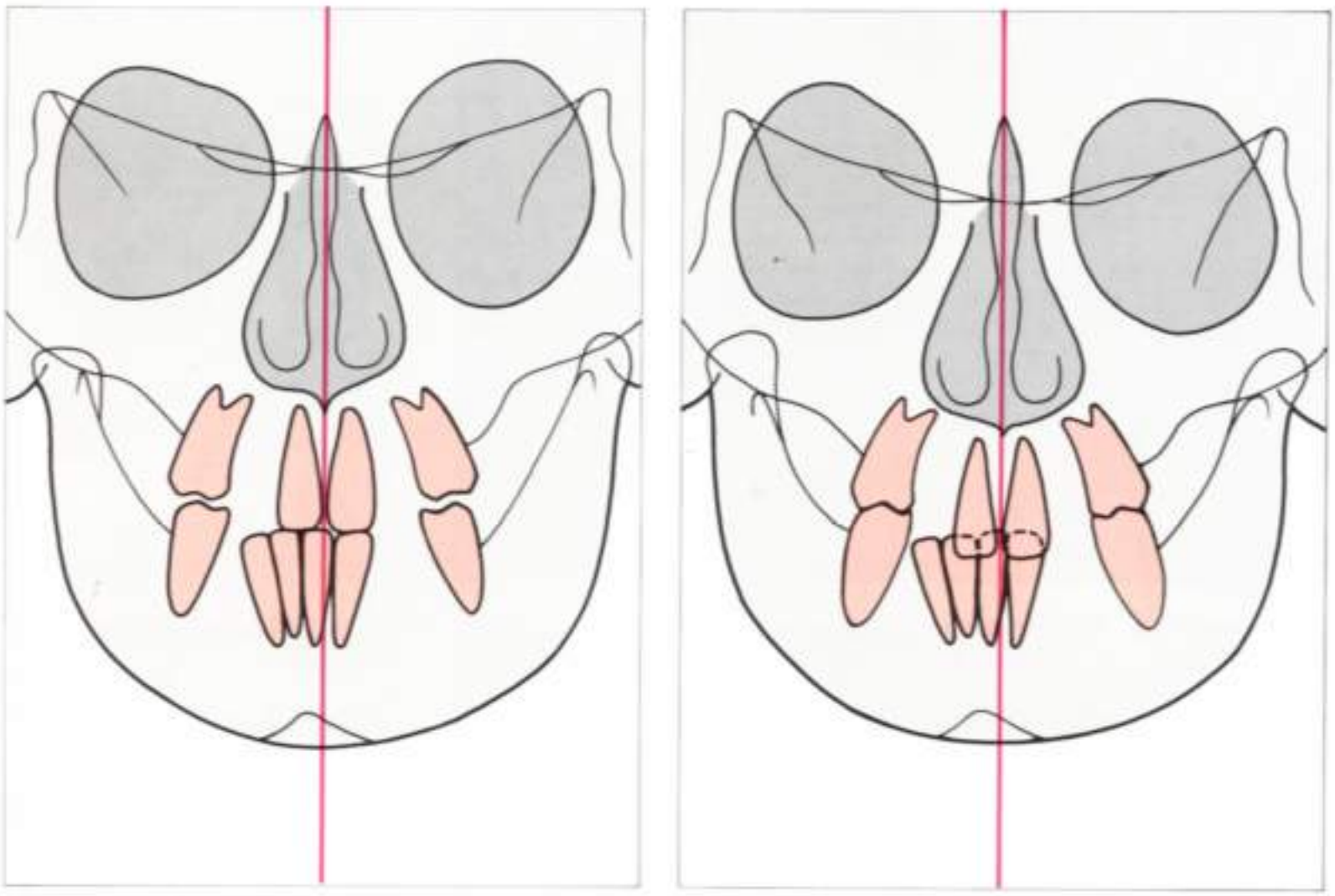
Class II, Division 2 malocclusion with a large freeway space in the postural resting position of the mandible. The prognosis for successful correction of the deep overbite is good, as this type of vertical maldevelopment can be treated with functional appliances and by extrusion of the molars. Lateral tongue-thrust and tongue posture are often associated with true deep overbite cases.

Evaluation of the Relationship between Rest Position and Habitual Occlusion in the Transverse Plane

The position of the midline of the mandible is observed while the jaw is moved from the postural rest to habitual occlusion. This analysis is particularly relevant for the differential diagnosis of cases with unilateral cross-bite. Depending on the functional analysis two types of skeletal mandibular deviation can be differentiated: laterognathy and lateroclusion.

Laterognathy. The center of the mandible is not aligned with the facial midline in rest and in occlusion. These dysplasias constitute true neuromuscular or anatomical asymmetry. A lateral cross-bite with laterognathy is termed true cross-bite. The prognosis is unfavorable for causal therapy (Fig. 327).

Lateroclusion. The skeletal midline shift of the mandible can be observed only in occlusal position; in postural rest both midlines are well aligned. The deviation is due to tooth guidance (functional non-true malocclusion) (Fig. 329).

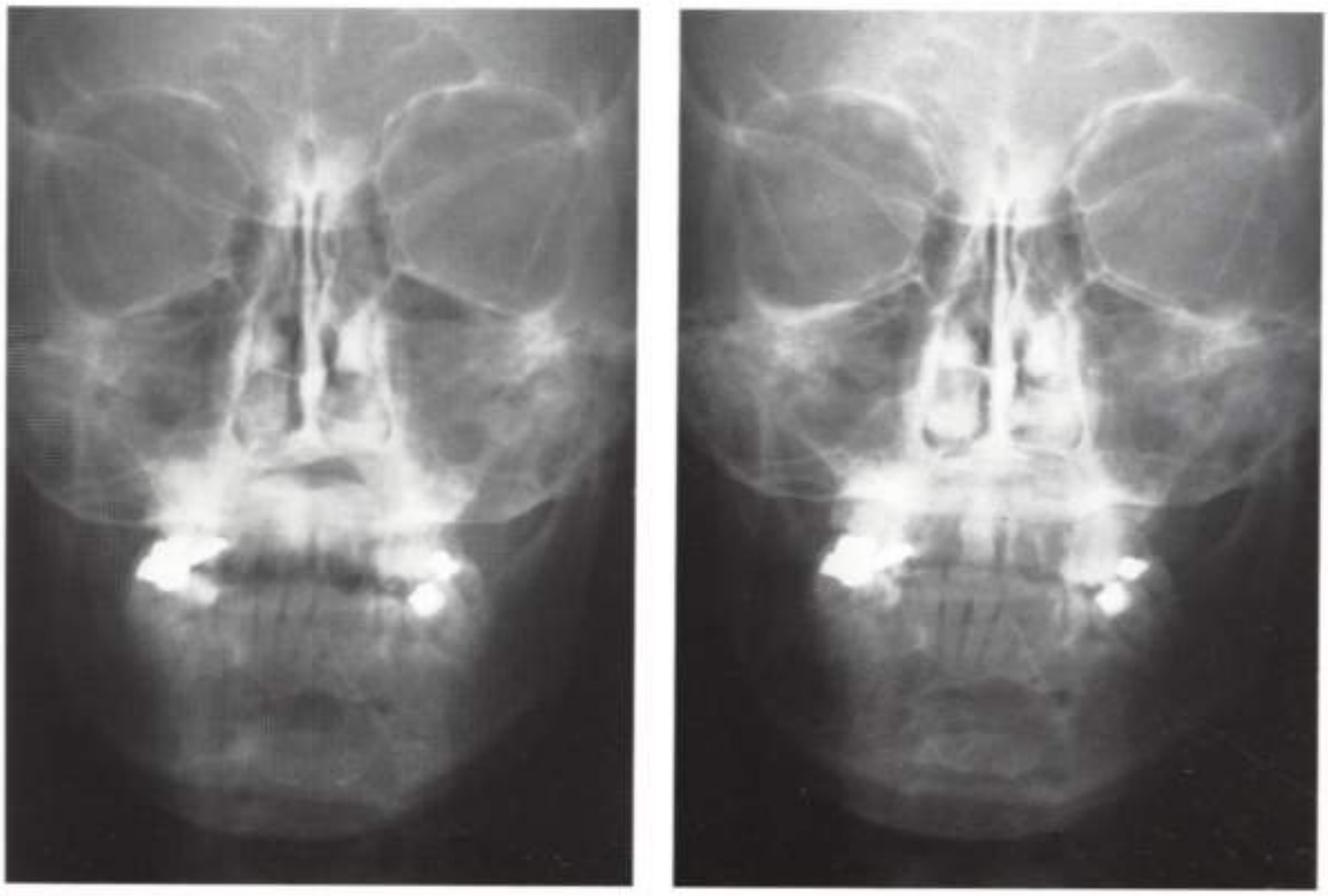


Mandibular midline shift: Laterognathy

327 Schematic illustration
Drawing showing the morphological relationships on the posteroanterior cephalogram in case of laterognathy.

Right: The center of the mandible is displaced in habitual occlusion. The skeletal midline of the lower jaw (mental spine) is shifted laterally in relation to the facial midsagittal plane (vertical line of reference).

Left: The lateral deviation of the mandibular midline in relation to the facial midline persists in the postural rest position.



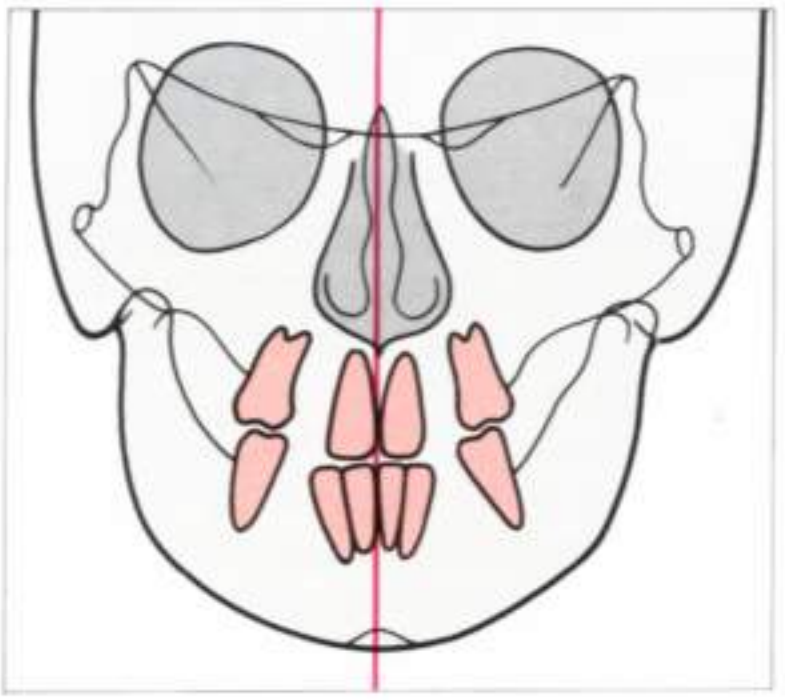
328 Findings in the posteroanterior cephalogram
Right: Radiograph of the patient in habitual occlusion.

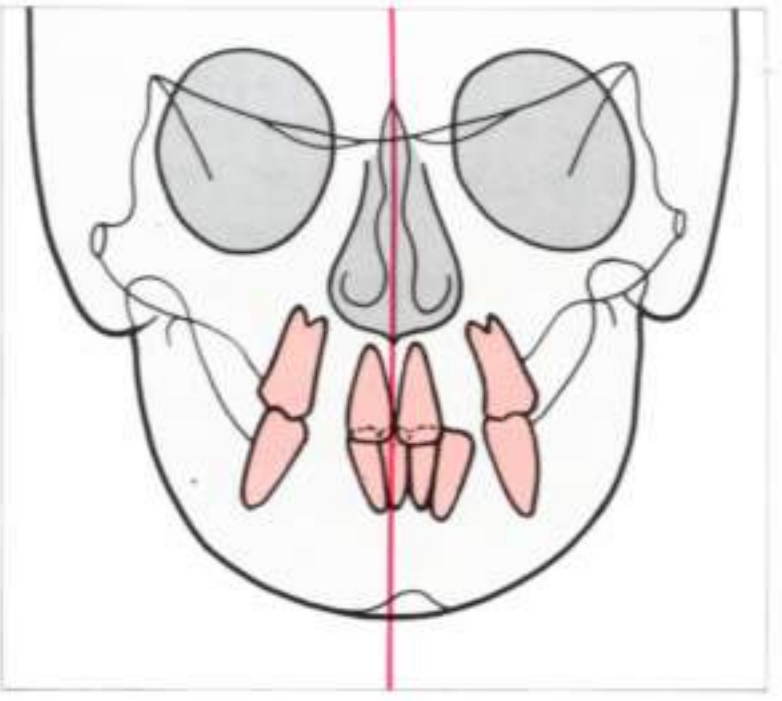
Left: Radiograph in the postural rest position.

The midline of the mandible is displaced toward the left in the occlusal position and in postural rest (laterognathy).

This lateral deviation originates in the skeleton and is associated with an asymmetric shape of the glenoid fossa and the condyles. Same female patient as in Figs. 281–283.

Mandibular midline shift: Laterocclusion





329 Schematic illustration
Morphologic relationships on the PA cephalogram of a case with lateroclusion.
Right: When in occlusal position, the midline of the mandible is displaced laterally from the facial midsagittal plane (vertical reference lines).

Left: In postural rest both midlines are coincident and well centered.

Relationship of postural rest to occlusal position

330 Postural resting position
In the rest position the center of the mandible is aligned with the upper midline. (The mesial contact point of the lower central incisors coincide with the skeletal midline of the mandible).

331 Initial tooth contact position
The mandible is in the initial tooth contact position, thus terminating the first phase of the closing movement, which started from the rest position. The patient's right lateral incisors contact prematurely.

332 Habitual occlusion
In the final phase of the closing action, after initial tooth contact, the mandible slides to the left.

Mandibular deviation in habitual occlusion is caused by tooth interferences, i.e. the skeletal midline shift of the mandible which is only present in maximum intercuspation signifies a functional malocclusion (lateroclusion).

Examination of the Temporomandibular Joint

Auscultation	Palpation	Functional analysis	Radiographic examination
Object			
• TMJ	• TMJ • Musculature	• TMJ • Mandibular excursions • Occlusion • Rest position • Premature contacts • Dysfunctions	• TMJ
Symptoms			
• Crepitus • Clicking	• Palpatory pain	• Dislocation • Hypermobility • Limitation • Deviation • Orofacial dysfunctions	• Dislocation • Changes in shape and structure

333 Clinical examination of the temporomandibular joint
This examination should include, as a matter of routine, the auscultation and palpation of the temporomandibular joint and the musculature associated with mandibular movements, as well as the functional analysis of the mandibular movements.

Specific radiographic examination of the temporomandibular joints, as a part of the orthodontic diagnosis, is only indicated in exceptional cases.

Clinical Examination

The main objective of the clinical examination is to assess the severity of the clicking, pain, and dysfunction which are characteristic of pathologic TMJ symptoms.

When *auscultation* is carried out with a stethoscope, clicking and crepitus in the joint may be diagnosed during anteroposterior and eccentric movements of the mandible. Joint clicking is differentiated as follows: Initial, intermediate, terminal, and reciprocal clicking. *Initial clicking* is a sign of retruded condyle in relation to the disc. *Intermediate clicking* is a sign of unevenness of the condylar surfaces and of the articular disc, which slide over one another during the movements. *Terminal clicking* occurs most commonly and is an effect of the condyle being moved too far anteriorly, in relation to the disc, on maximum jaw opening. *Reciprocal clicking* occurs during opening and closing, and expresses an incoordination between displacement of the condyle and disc. Clicking of the joint is rare in children.

Palpation of the temporomandibular joint during opening maneuvers will reveal possible pain on pressure of the condylar areas. Besides the right and left condyles can thus be checked for synchrony of action. In children, pain due to pressure on the joints only occurs in approximately 5% of cases.

Palpation of the *musculature* involved in mandibular movements is a considerable part of the examination. Some authors (Krogh-Poulsen, 1973) recommend palpating not only the masticatory musculature of adult patients but also the entire muscles of the head, face, and neck. Our experience has shown that in cases with functional disturbances during childhood only one muscle regularly causes pain due to pressure: the lateral pterygoid muscle. Masseter muscle pain is also encountered in children with TMJ problems. Therefore, these muscle attachments should be examined on every orthodontic patient as a matter of course. In most patients, the initial symptom of TMJ disturbances is considerable palpatory tenderness in these areas of the muscles, which usually occurs on both sides. If bilateral pain to palpation of the lateral pterygoid area is present, the joint dysfunction is more protracted. In these patients, the palpation findings of other jaw muscles is sometimes positive, i.e. it only makes sense to palpate the attachments of the remaining associated muscles in cases of bilateral or manifest pressure sensitivity of the lateral pterygoid.

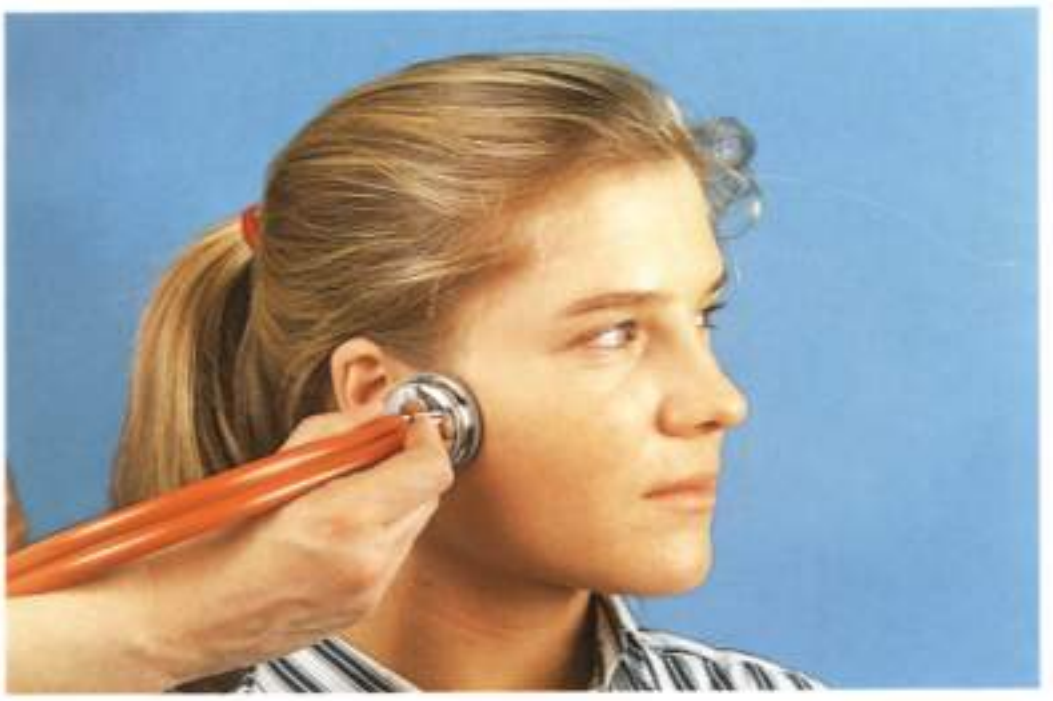
334 Local, clinical findings of the temporomandibular joints
Compilation of pathologic findings of the temporomandibular joint to be noted by clinical functional analysis.

Auscultation and palpation of the TMJ
– Clinical findings –

- Pain on pressure
- Clicking of the joint
  - initial
  - intermediate
  - terminal
  - reciprocal
- Crepitus
- Uncoordinated condyle movements

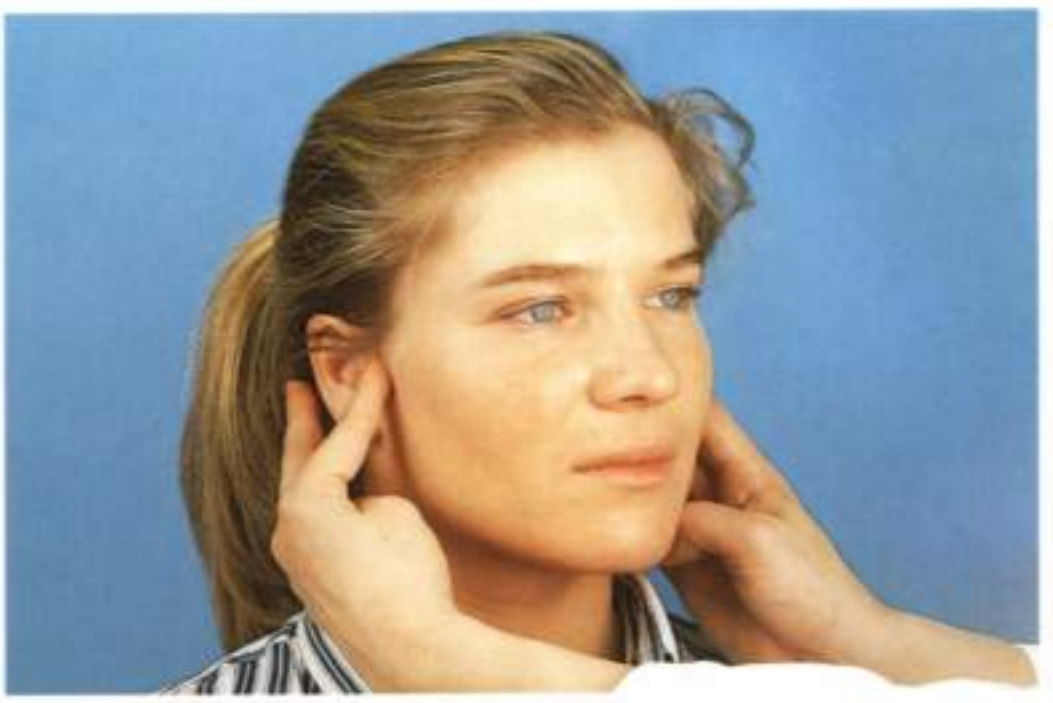
335 Auscultation of the temporomandibular joints
Sounds made by the temporomandibular joints can be evaluated with a stethoscope. Even slight abnormal sounds can thus be registered.

Also the timing of clicking during opening and closure should be noted: Initial, intermediate, terminal, or reciprocal.



336 Lateral palpation of the temporomandibular joints
Exert slight pressure on the condyloid process with the index fingers. Palpate both sides simultaneously.

Register any tenderness to palpation of the joints and any irregularities in condylar movement during opening and closing maneuvers. The coordination of action between the left and right condylar heads should be assessed at the same time.



337 Posterior palpation of the temporomandibular joints
Position the little fingers in the external auditory meatus and palpate the posterior surface of the condyle during opening and closing movements of the mandible.

Palpation should be carried out in such a way that the condyle displaces the little finger when closing in full occlusion.

338 Palpation of the lateral pterygoid muscle

The pain projection area of the lateral pterygoid muscle is palpated in close proximity to the neck of the condyle and the joint capsule, cranially behind the maxillary tuberosity. The examination is carried out with the mouth open and the mandible displaced laterally.

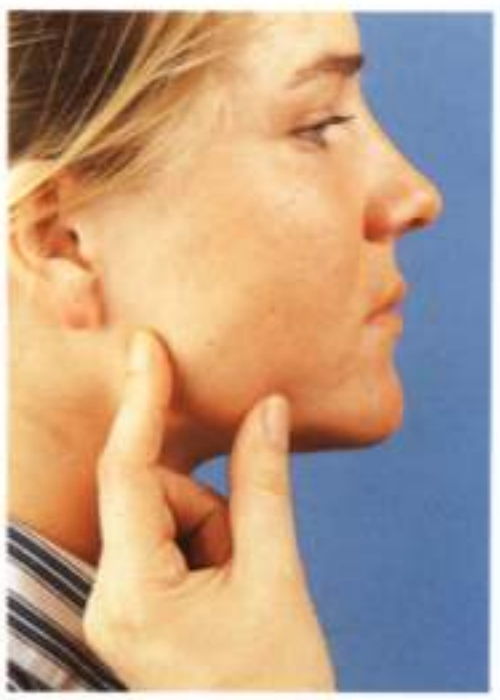
In the initial stages of TMJ dysfunction, the muscle often hurts upon palpation on one side only. In the advanced stage the pain is usually bilateral.

339 Palpation of the temporalis muscle

The temporalis muscle is palpated bilaterally and extraorally. The anterior, medial, and posterior portions of the muscle are examined separately.

The palpation is carried out while the muscle is contracted isometrically.

Left: The temporal tendinous attachment on the coronoid process, in the posterolateral region of the upper vestibulum, is palpated. The patient's mouth should be half open for the examination.



340 Palpation of the masseter muscle

The superficial masseter muscle is palpated beneath the eye, inferior to the zygomatic arch.

The deep portion is palpated on the same level, approximately 2 finger widths in front of the tragus.

Left: During maximum isometric muscle contractions the width of the superficial masseter and its direction of pull can be registered around the gonial angle. This muscle attachment should be examined for pain on to pressure. Occasional trigger spots may occur which can be quite painful.

341 Recording the maximum interincisal distance

On maximum jaw opening, the distance between the incisal edges of the upper and lower central incisors is measured with a Boley gauge.

In overbite cases this amount is added to the obtained value whereas in open bite it is subtracted. The extent of maximum jaw opening between the incisal edges is usually 40–45 mm. In cases with TMJ dysfunction, hypermobility is often registered in the initial stages and limitation in the later stages.

Opening and Closing Movements of the Mandible

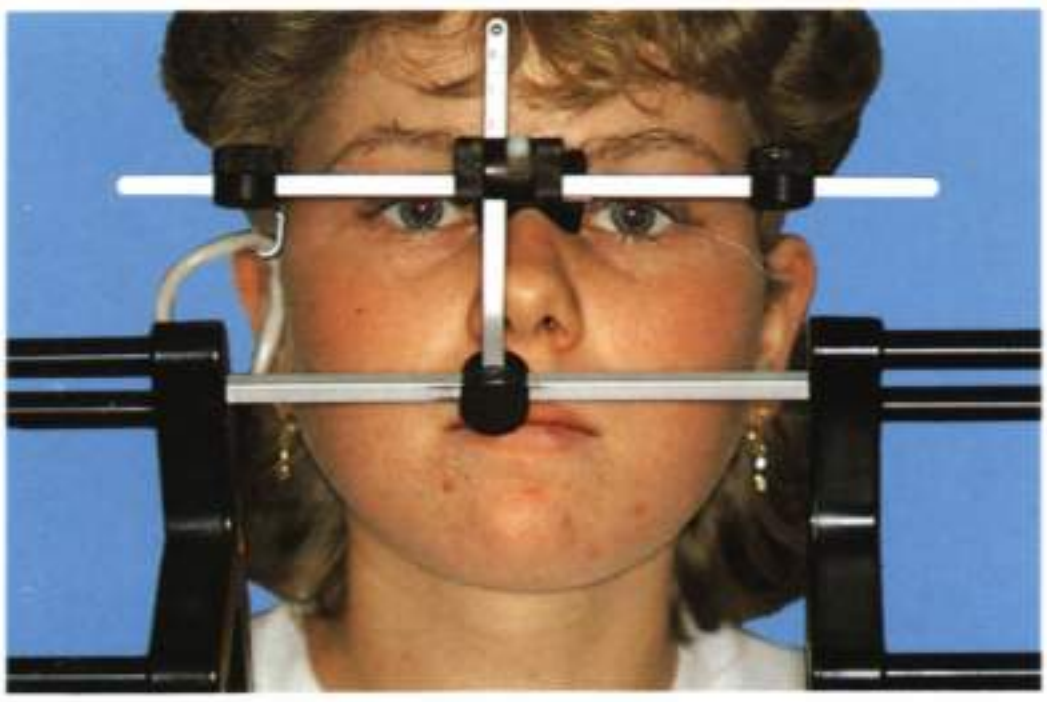
The opening and closing movements of the mandible as well as its protrusive, retrusive and lateral excursions are examined as part of the functional analysis. *The size* and *direction* of these actions are recorded during the clinical examination. Deviations in speed can only be registered with electronic devices (e.g. kinesiograph).

The first signs of initial temporomandibular joint problems include deviations of the mandibular opening and closing paths in the sagittal and frontal planes. In patients with malocclusion and malaligned teeth, disturbances in mandibular movements are the result of an asynchronic pattern of muscle contractions. The characteristic movement deviations include incongruency of the opening and closing curves and uncoordinated zigzag movements. The "C" and "S" types of deviation are typical signs of functional disturbances.

Occlusal analysis on an articulator is mostly not necessary in adolescents. It is only indicated in patients with manifest symptoms of temporomandibular joint disease.

Interference-free registration of mandibular opening and closing movements

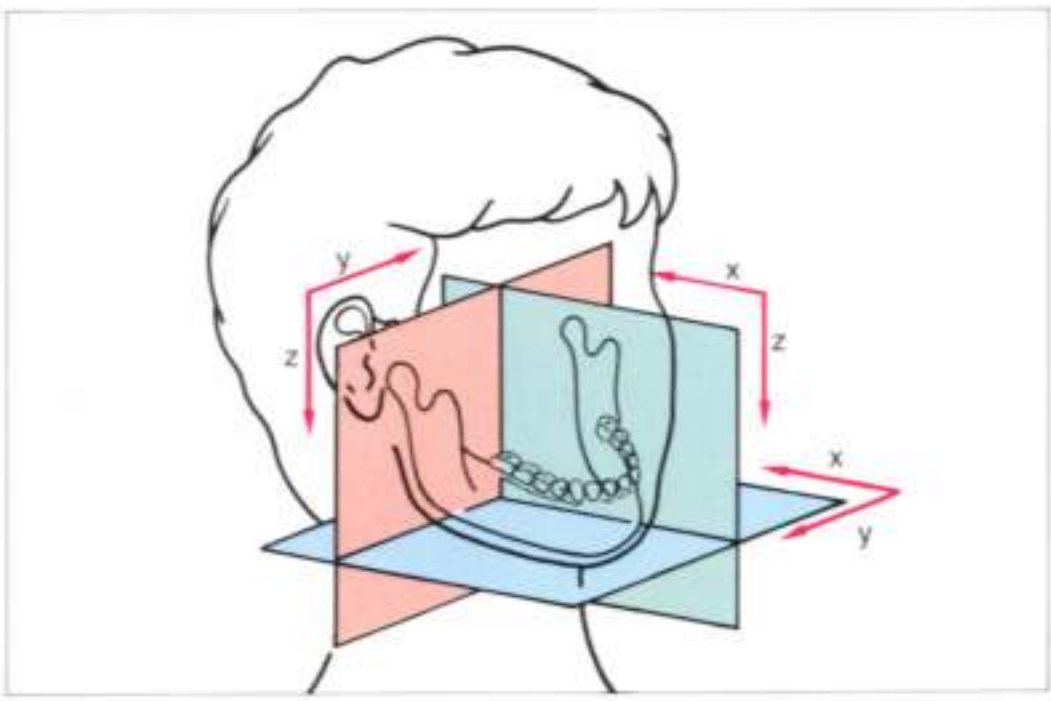
342 Head frame of the electronic recording unit
Frontal and lateral view of the head frame in position. A permanent magnet is secured intraorally on the mandible to produce a three-dimensional magnetic field. The head frame consists of a system of antennas which record the changes in position of the magnetic field during movements of the mandible (Sirognathograph, Siemens, Bensheim, Germany).



343 Coordinate system
The changes in position of the magnetic field during mandibular movements, and the antenna signals, are converted to analog electrical charges which are fed into a processor and displayed as three reference values: x, y and z.

These can be graphically presented via a plotter in one of the following three facial planes:

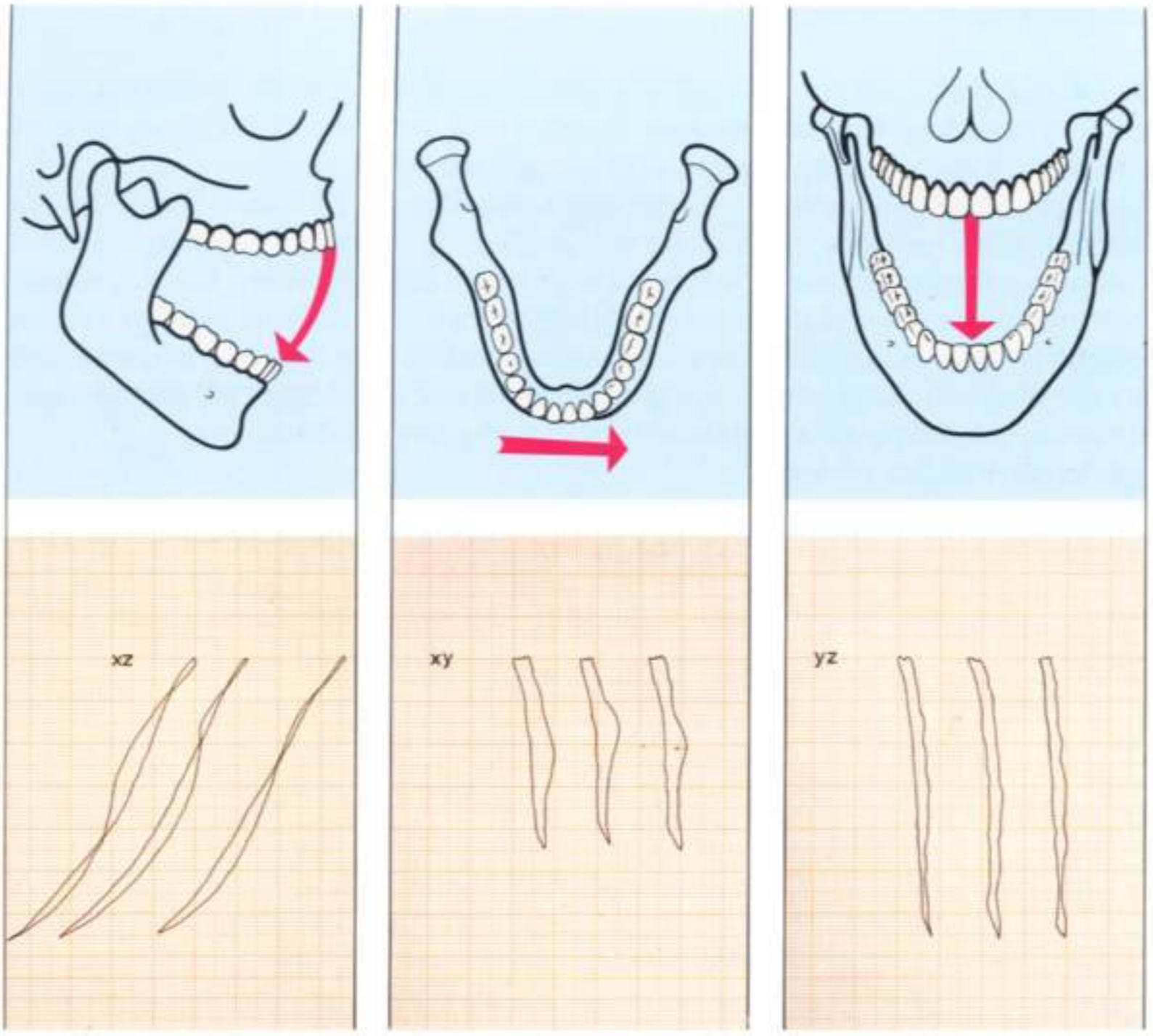
XZ plane = Sagittal plane
XY plane = Horizontal plane
YZ plane = Frontal plane



Case example
Figs. 344–346

344 Occlusal relationships
Frontal and lateral view of the habitual occlusion of a 21-year-old female patient.

The left lateral incisors are in edge-to-edge relationship. There is severe attrition of the upper canines.



345 Pattern of mandibular movements during opening and closing maneuvers

Left: Opening and closing paths in the sagittal plane (XZ plane).

The opening and closing arcs cross-over inconsistently.

The opening movements show greater deviations.

The closure pattern is straighter and more constant.

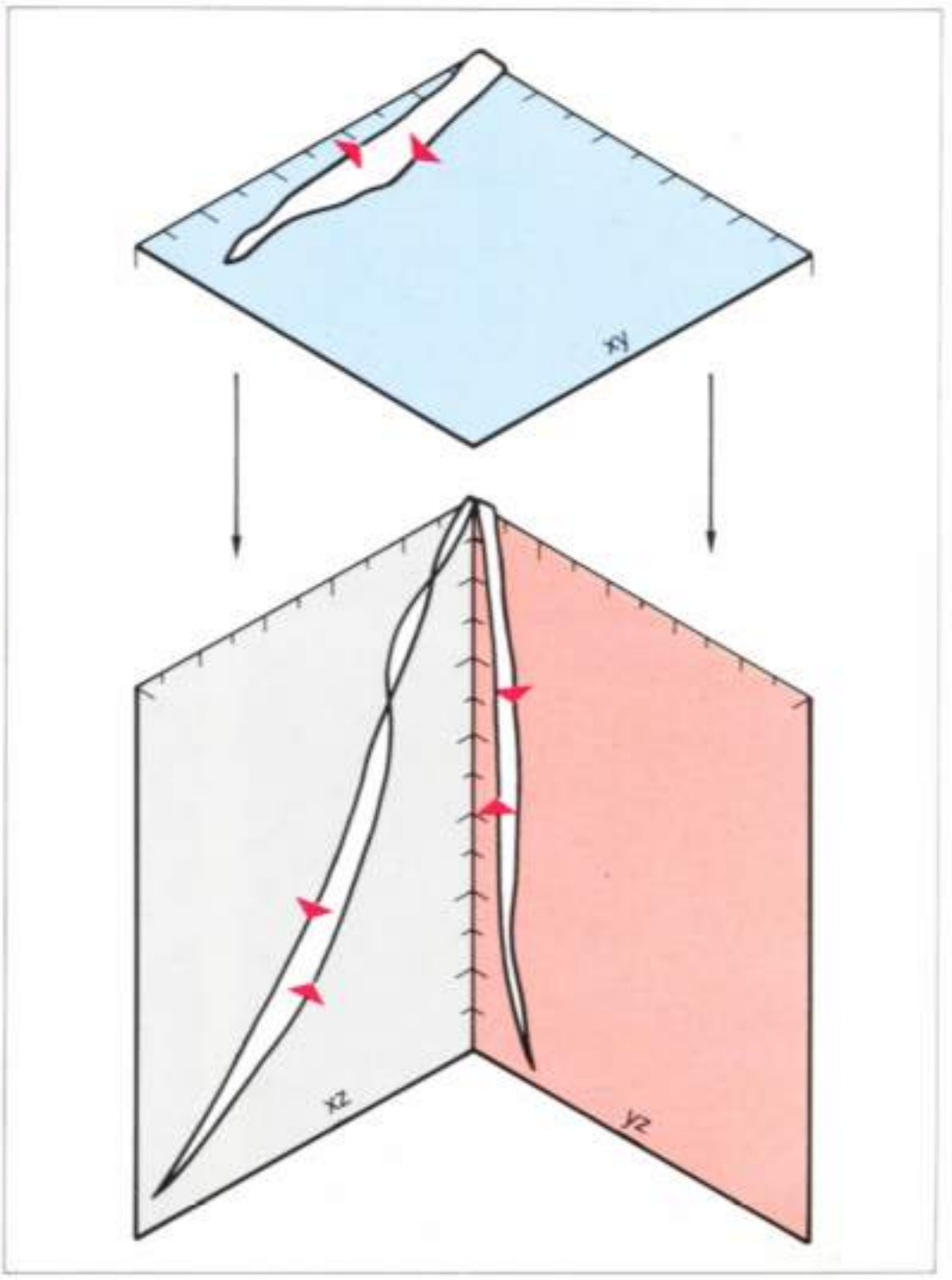
Center: Opening and closing arcs in the horizontal plane (XY plane).

The opening path is pathologically C-shaped.

At the end of the closing movement, the mandible shifts slightly toward the left.

Right: Opening and closing paths in the frontal plane (YZ plane).

The extent of maximum jaw opening is normal. During the final stages of closing, the mandible slides to the left due to occlusal interferences (1 millimeter = 0.5 mm movement).



346 Three-dimensional reconstruction of the mandibular opening and closing movements

Three-dimensional diagram of the recordings shown in Fig. 345 (marking of the opening and closing arcs).

Left: The attrition on the upper left canine of this female patient is a clinical symptom of the occlusal interference. The occlusal relationships are shown in Fig. 344.

Temporomandibular Joint – Radiographic Examination

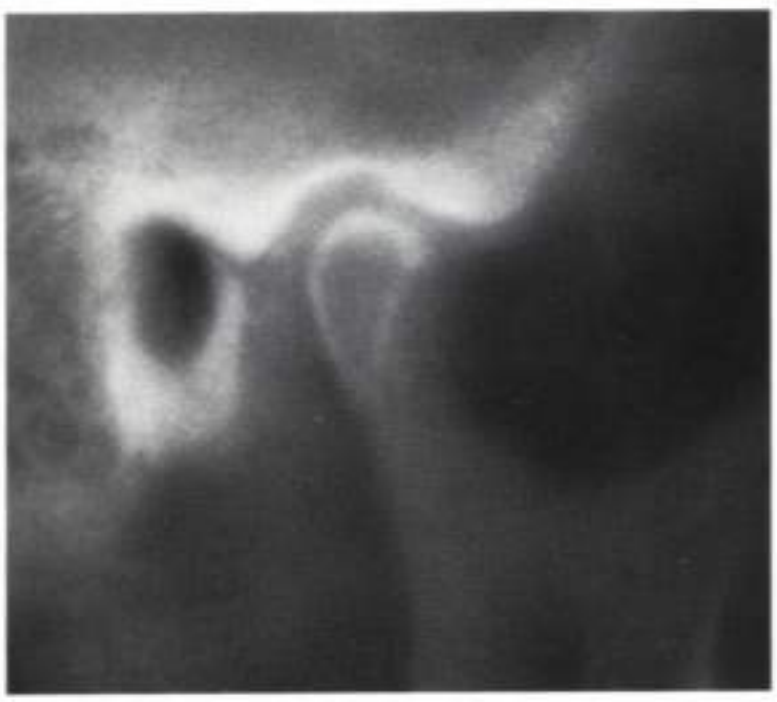
Only in exceptional cases are radiographic examinations indicated for children with functional disturbances of the temporomandibular joint. In contrast to adults, pathologic radiographic findings are rare at this early age. Several radiographic techniques, which are taken in habitual occlusion and/or in open-mouth position, are suitable for examination of the temporomandibular joints (posteroanterior projections according to Clementschitsch, radiographs according to Schüller or Parma, tomograms). When analyzing the radiographs, the following findings are registered: Position of the condyle in relation to the fossa, width of the joint space, changes in shape and structure of the condylar head and/or the mandibular fossa.

Adolescents with Class II, Division 1 malocclusions and lip dysfunction (lip-biting or sucking) are most frequently affected by TMJ disorders. For this reason, orofacial dysfunctions must also be assessed as a part of the functional analysis as they may lead to unbalanced loading of the joints and thus trigger off temporomandibular joint disturbances in adolescents.

Radiographic examination of the temporomandibular joints – case example –

347 Clinical findings
22-year-old patient with a pronounced lip dysfunction.

Right: Class II malocclusion with increased overjet and labioversion of the upper incisors.



348 Tomograms of the temporomandibular joint in habitual occlusion
Tomographic film of the right and left temporomandibular joints in full intercuspation (projected along the sagittal plane).

There are noticeable differences between the left and right sides regarding the shape of the condyles, the roof of the fossa, and the width of the joint space.

Right: The condyle and the roof of the fossa are flattened severely; the condyle is dislocated anteriorly in the glenoid cavity.

349 Tomograms of the temporomandibular joint in maximum open-mouth position
Left: The right condyle is subluxated when the jaw is maximally opened.

Right: The vertex of the left condyle is positioned beneath the articular tubercle.

Examination of Orofacial Dysfunctions

- Swallowing
- Tongue
- Speech
- Lips
- Respiration

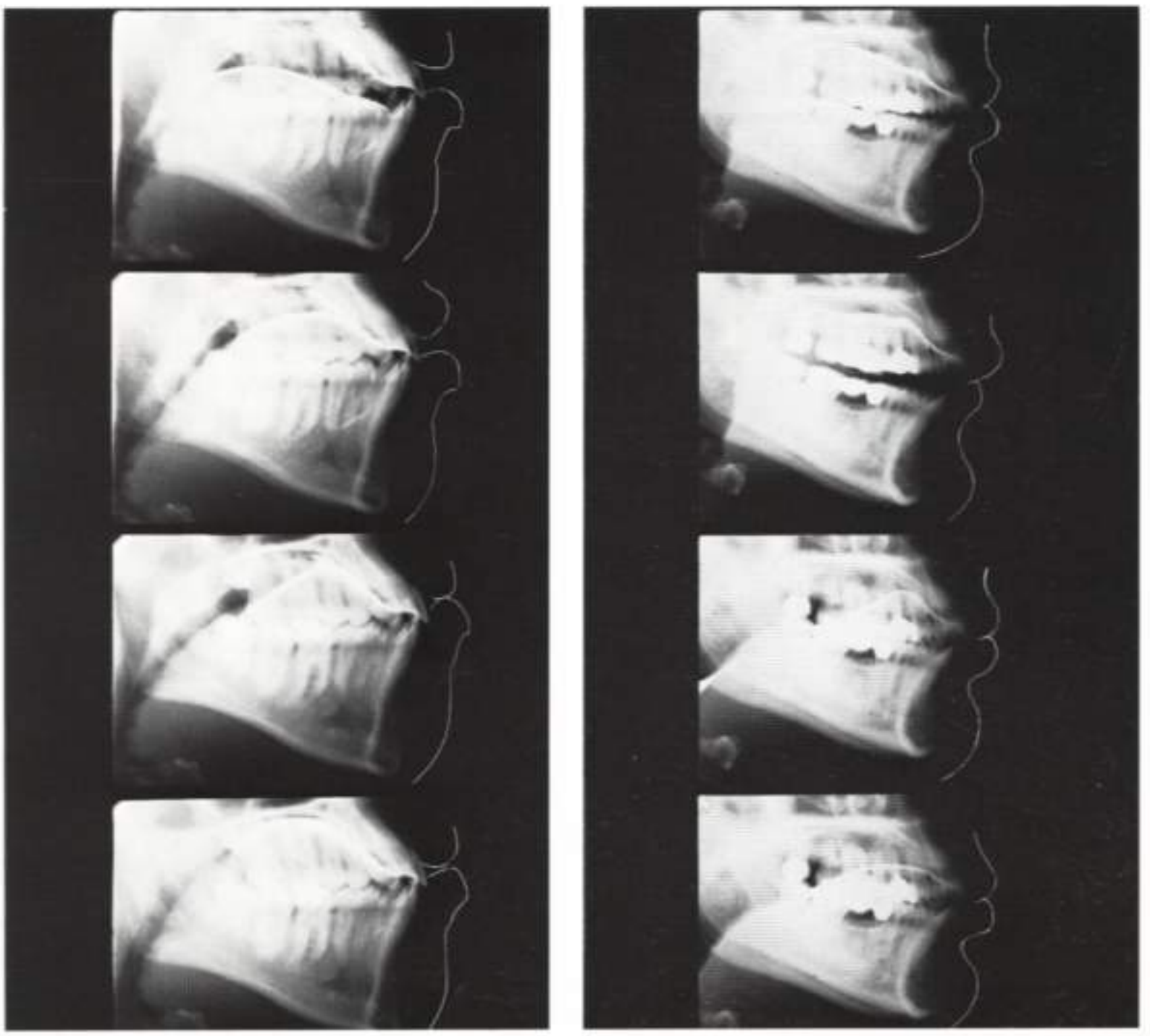
Swallowing

Normal mature swallowing takes place without contracting the muscles of facial expression. The teeth are momentarily in contact and the tongue remains inside the mouth (Fig. 350).

Abnormal swallowing is caused by *tongue-thrust,* either as a simple thrusting action or as *"tongue-thrust syndrome"*. The following symptoms distinguish this syndrome: 1) Protrusion of the tip of the tongue, 2) no tooth contact of the molars, 3) contraction of the perioral muscles during the deglutitional cycle.

During their first few years, infants swallow *viscerally,* i.e. with the tongue between the teeth (Fig. 359). As the deciduous dentition is completed, the visceral swallowing is gradually replaced by *somatic* swallowing.

Should visceral swallowing persist after the fourth year of age, it is then considered an orofacial dysfunction. Infantile swallowing is seldom found in older children and, even if it occurs, then only as a mixed type of visceral/somatic swallowing.



350 Cinematography of swallowing

Cineradiographic images of individual stages of the deglutitional cycle during saliva swallowing.

Left: From top to bottom; sequence of movements of somatic swallowing. The tip of the tongue is enclosed in the oral cavity during swallowing; the upper and lower posterior teeth contact one another during the deglutition cycle.

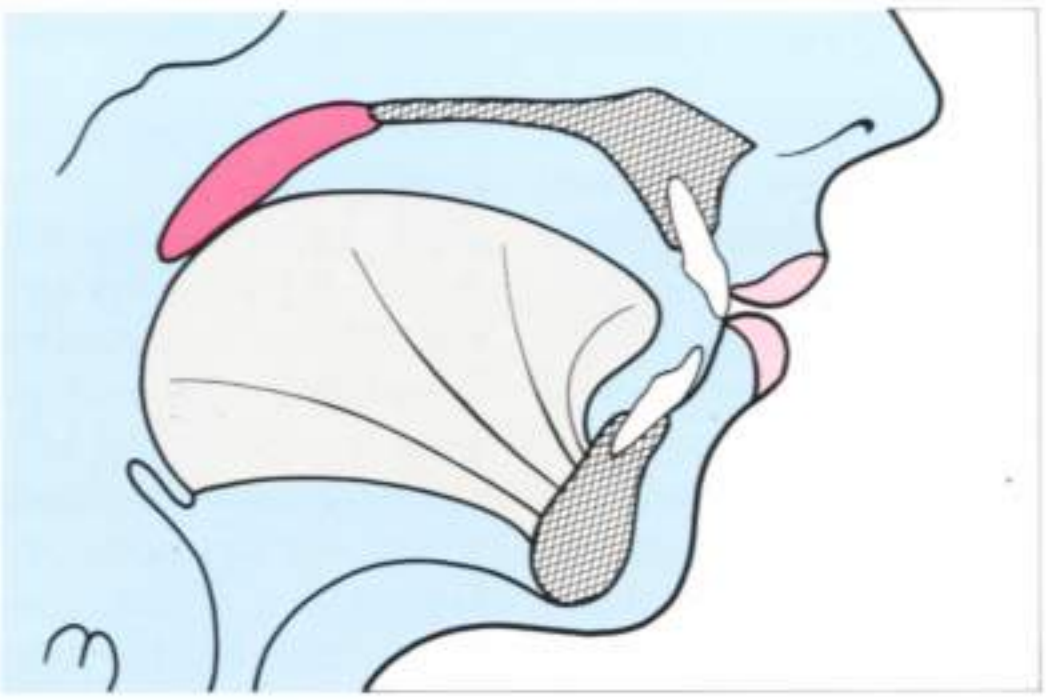
Right: Sequence of activity during visceral swallowing.

The tip of the tongue protrudes and attempts to reach the lower lip. The upper and lower posterior teeth do not come into contact during the entire sequence of movements (the dorsum of the tongue is marked with a contrast medium).

351 Tongue peristalsis during somatic swallowing – Collecting stage

During the first stage of swallowing, the food is collected in the foremost part of the mouth, in front of the retracted tongue. The posterior arched part of the dorsum is in contact with the soft palate.

The lips are not in contact and the teeth are not occluding.



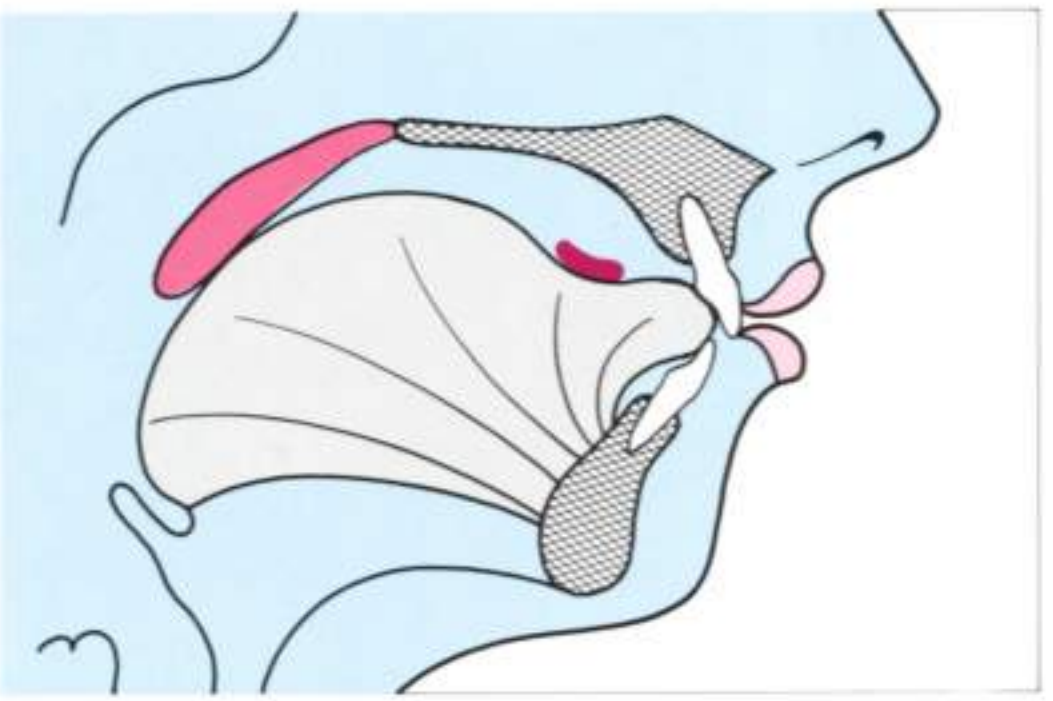
352 Physiologic variations during the collecting stage

There are certain variations in the first stage of the swallowing cycle. The food may be taken in front of the retracted tongue.

Right: In other cases, the food bolus is collected on the dorsum of the tongue (cineradiography).

353 Transporting stage – 1st part of movement

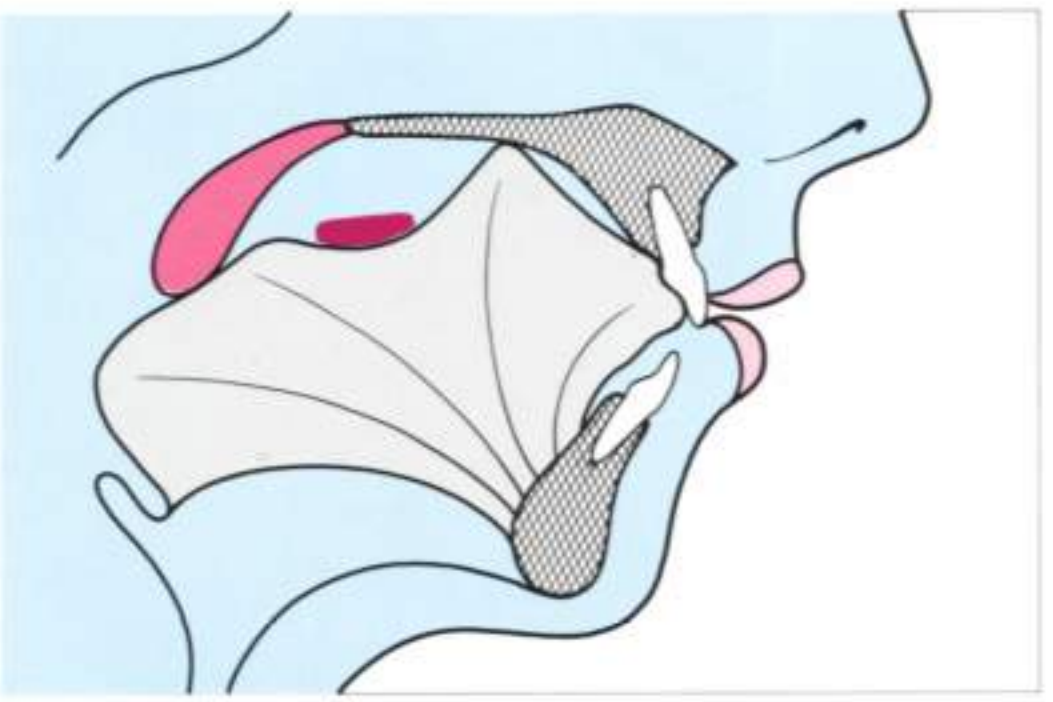
During the second phase of swallowing, i.e. the transporting stage, the tip of the tongue first moves upward and the anterior section of the dorsum is depressed (according to *Graber,* 1972).

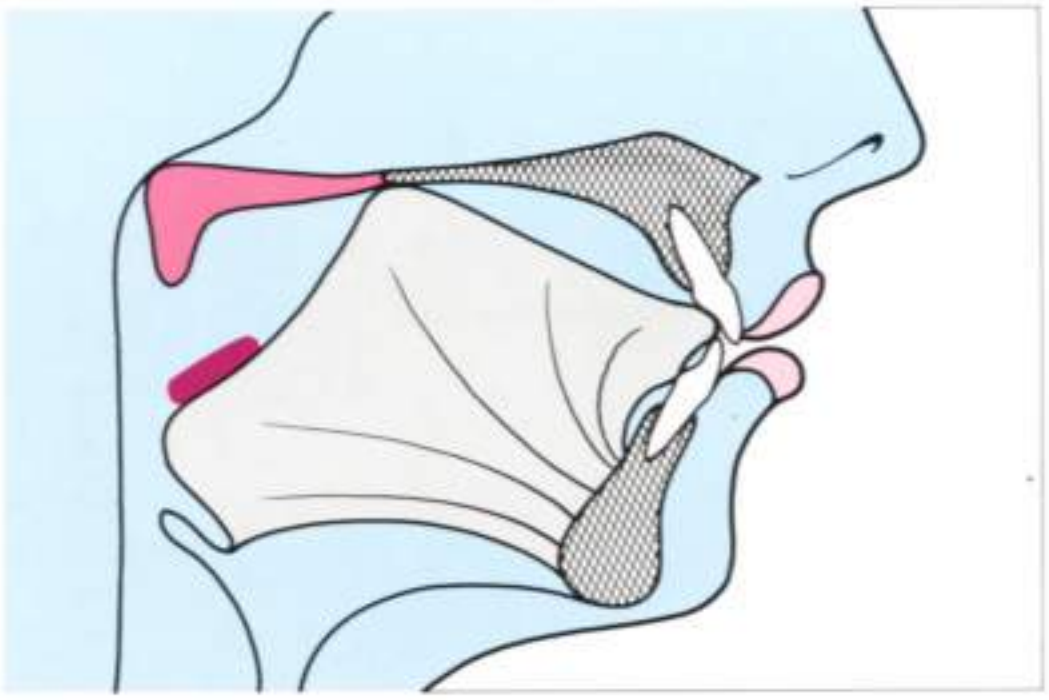


354 Transporting stage – 2nd part of movement

The entire anterior section of the tongue then moves upward and the central section of the dorsum is depressed.

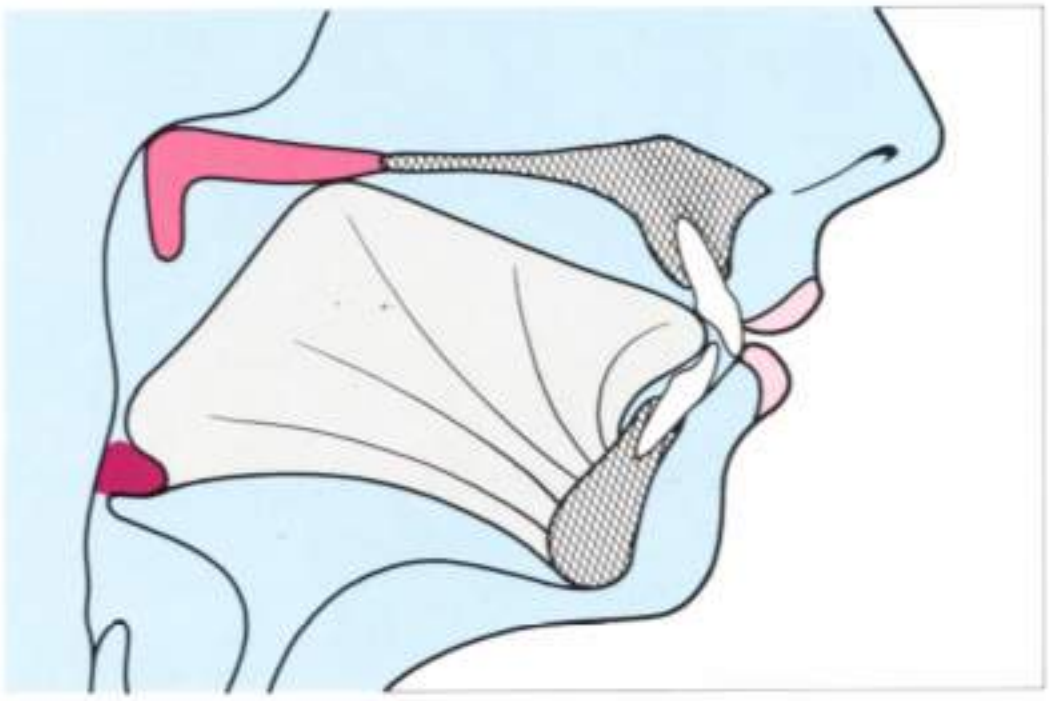
This peristalsis transports the bolus rearward.





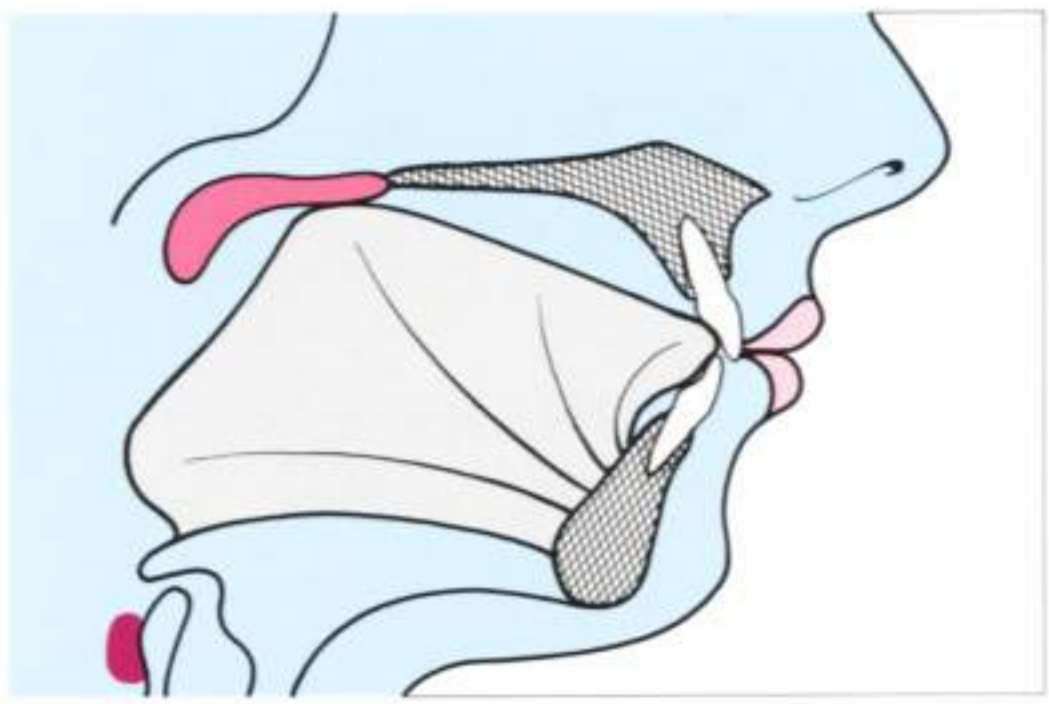
355 Transporting stage – 3rd part of movement
At the end of the transporting stage, the soft palate is displaced upward and rearward.

The lip musculature contracts simultaneously, the lips are together, the mandible is raised and the teeth come into contact.

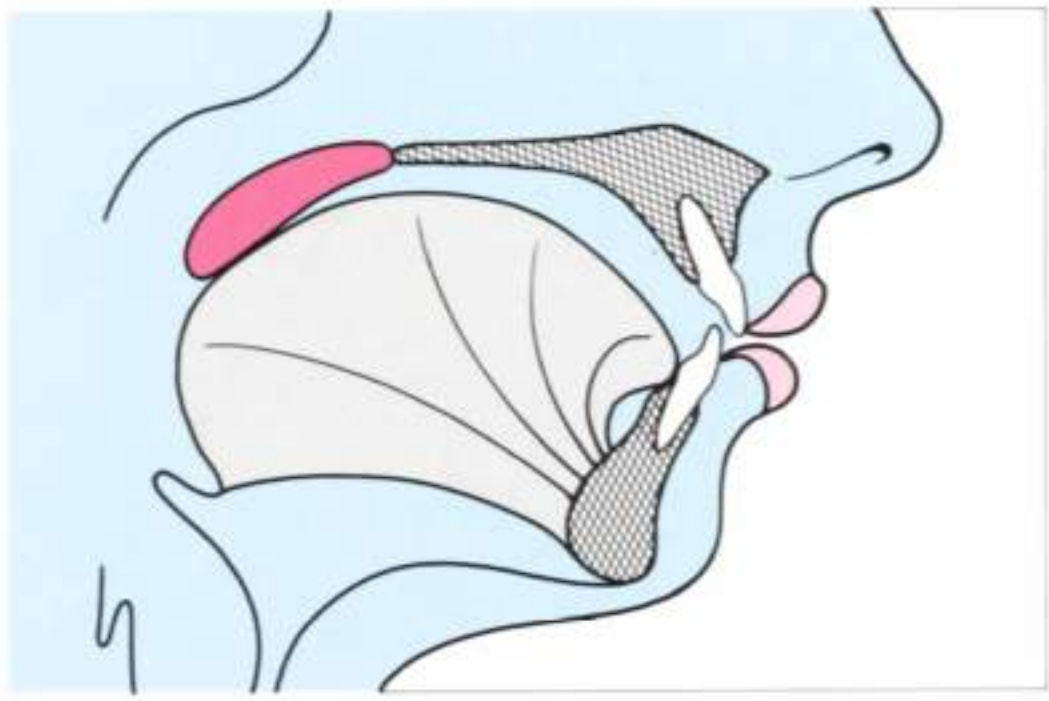


356 Third swallowing stage
The dorsum of the tongue is depressed even further during the third stage so that the bolus can pass through the oropharyngeal isthmus; simultaneously the anterior part of the tongue is pressed against the hard palate, thus forcing more food rearward.

Passavant's pad and soft palate form the palatopharyngeal seal and close the nasopharynx. The teeth are in full occlusion and the lips in contact.



357 Fourth swallowing stage
During the fourth stage of the swallowing act, the dorsum of the tongue is moved further upward and rearward against the soft palate and squeezes the remaining food bolus out of the oropharyngeal area.



358 Final stage of swallowing cycle
Once the swallowing act has been completed, the mandible returns to its rest position.

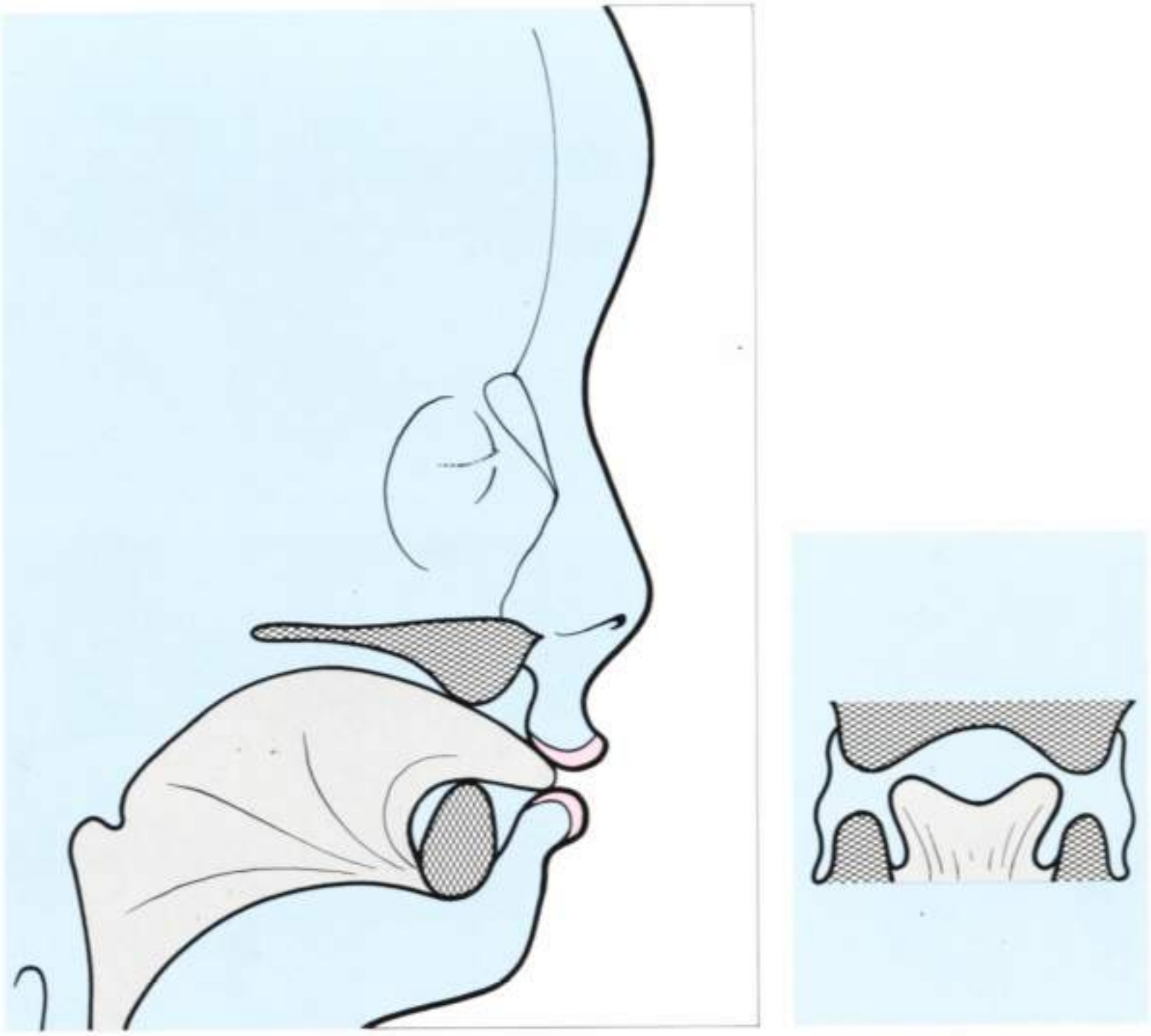
359 Visceral (infantile) swallow in the neonate

The jaws are apart during swallowing. The tongue is pushed forward and placed between the gum pads. The tip of the tongue protrudes.

The mandible is stabilized by the contraction of the tongue and the orofacial musculature as well as by the tongue contact with the lips.

Swallowing is triggered off and, to a large extent, carried out by sensory interchange between the lips and the tongue. Peristalsis already commences in the vestibule.

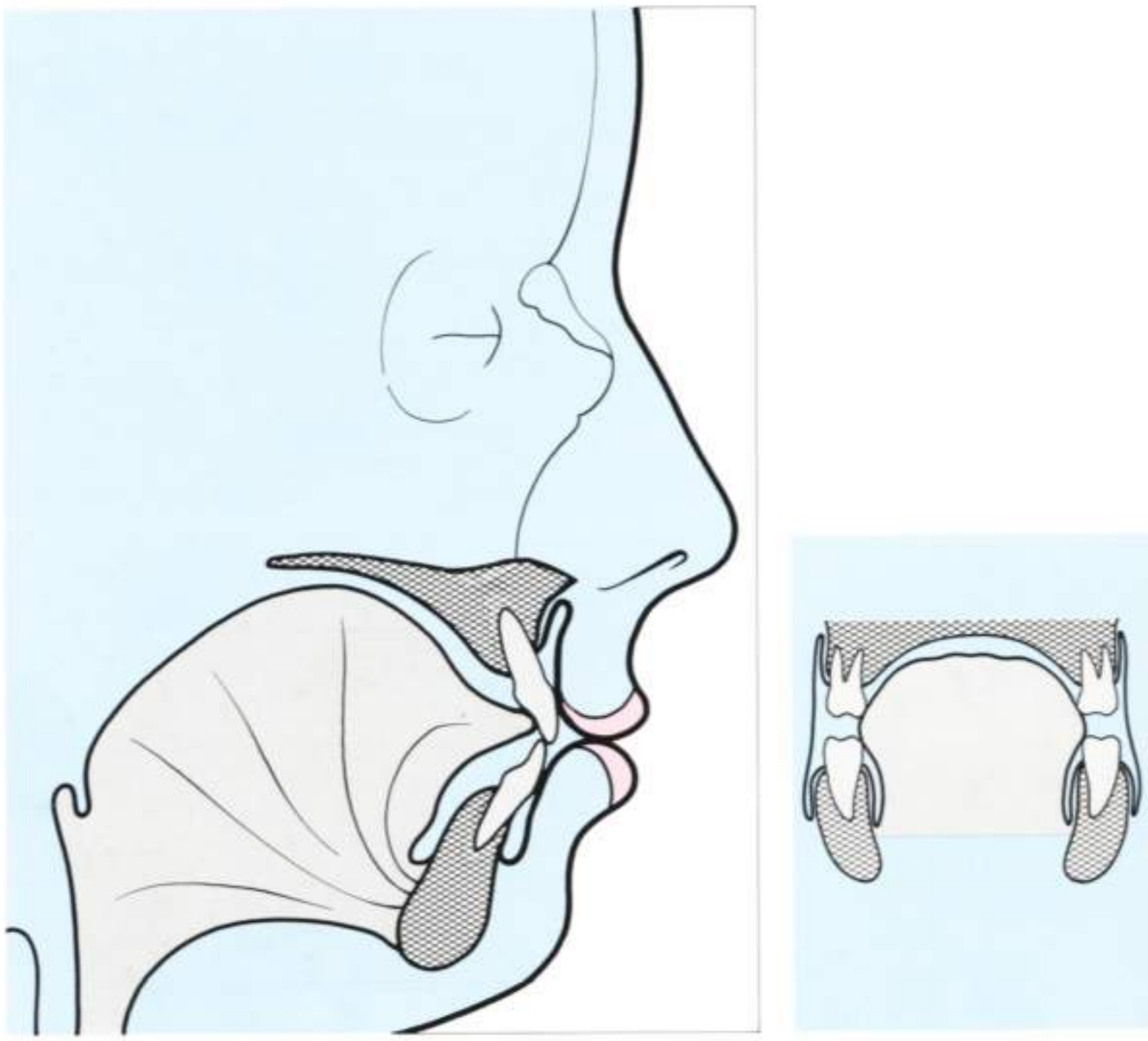
Right: The transverse section shows that the tongue is positioned low in the mouth and that the central furrow is depressed (according to *Graber*, 1972).



360 Somatic swallow

As swallowing is triggered off by contraction of the mandibular elevators (masseter muscle), the teeth occlude momentarily during the swallowing act and the tip of the tongue is enclosed in the oral cavity.

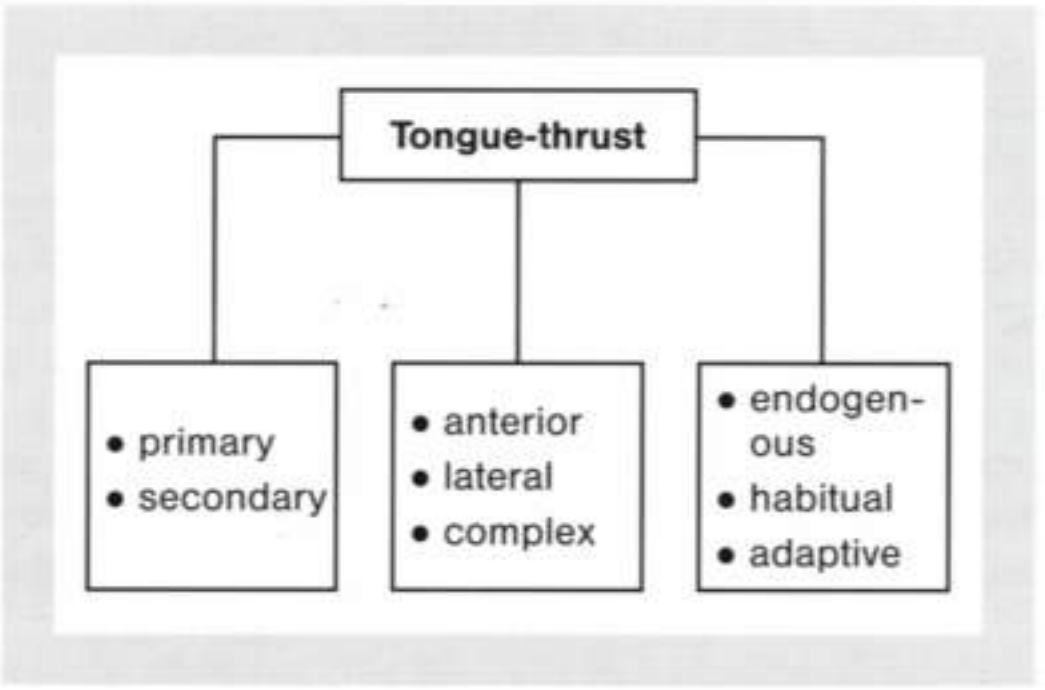
Right: The transverse section shows that the dorsum of the tongue is less concave and approaches the palate during swallowing (according to *Graber*, 1972).



Tongue-Thrust

Tongue-thrust has an important effect on the etiopathogenesis of malocclusions (Fig. 361). The thrust may take place in the *anterior* or *lateral* regions or can be *complex*. In the first case, the dysfunction is significant during the development of an anterior open bite (Figs. 362, 363) and in the second case during the development of a lateral open bite (Figs. 364, 365) or a deep overbite. In case of a complex tongue-thrust, the occlusion is supported only in the molar region (Fig. 366).

Cases with an anterior open bite during childhood (Figs. 362, 363) are often self-compensating. Complex or skeletal open bites do not regulate themselves spontaneously, but rather persist.



361 Etiology of tongue-thrusting
Table showing the different causes and divergent localization of the dysfunction.

Anterior open bite

362 Occlusion
Open bite in a deciduous dentition, caused by a tongue dysfunction as a residuum of a sucking habit.

363 Habitual position
The tongue is positioned forward during functioning, thus impeding the vertical development of the dentoalveolar structures around the upper and lower anterior teeth.
Same patient as in Fig. 362.

Lateral open bite

364 Occlusion
In this type of open bite the occlusion on both sides is supported only anteriorly and by the first permanent molars.

365 Habitual position
The tongue thrusts between the teeth laterally.

The tongue dysfunction occurs in conjunction with a disturbance in the physiologic growth processes around the first and second deciduous molars.

Same patient as in Fig. 364.

366 Complex open bite
Severe vertical malocclusion. The teeth occlude only on the second molars. Tongue-thrusting occurs during function.

367 Tongue dysfunction and malocclusion
In mandibular prognathism, the downward forward displacement of the tongue often causes an anterior tongue-thrust habit.

Primary – Secondary Dysfunctions

From the etiologic point of view, tongue-thrust may be considered *primary* or *secondary*. Principally speaking, all dysfunctions can be divided into primary, i.e. causal or secondary, i.e. adaptive malfunctions (Fig. 368).

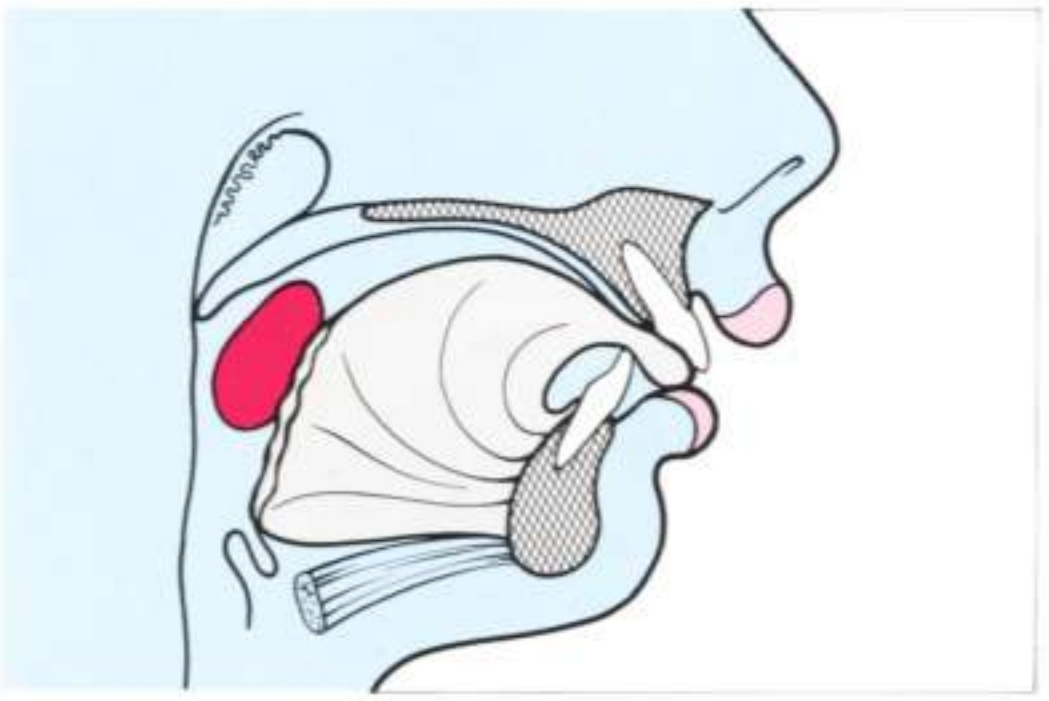
The primary dysfunctions cause malocclusions (Figs. 369 and 370) and the treatment must concentrate on eliminating the orofacial dysfunction.

Secondary dysfunctions can be considered an adaptive phenomenon to an existing skeletal or dento-alveolar deviation in the vertical development (Figs. 371–373). These secondary abnormalities usually correct spontaneously while the morphological discrepancies are being treated (homeostasis).

Causes of dysfunctions

Primary	Secondary
• Endogenous factors • Heredity • Imitation	• Adaptation

368 Etiology of primary and secondary orofacial dysfunctions
Compilation of the various causes.



369 Primary tongue dysfunction in conjunction with hyperplastic tonsils
A retracted tongue would touch infected, swollen tonsils if these were to protrude far out of the surrounding structures. In order to avoid painful sensations and to keep the oral airway open the mandible is dropped and the tongue postured forward (according to *Moyers*).

370 Hyperplastic tonsils
Moderately swollen palatine tonsils which protrude significantly from the tonsillar sinus.

Adaptive tongue dysfunction

371 Adaptive tongue dysfunction with tooth malpositions
After loss of teeth, the tongue is used to fill the gaps, thus sealing the oral cavity, i.e. compensatory dysfunction.

In cases with premature extraction of deciduous teeth, this primarily physiologic displacement of the tongue may persist as a functional abnormality even after the permanent teeth have erupted.

372 Adaptive tongue dysfunction with skeletal malocclusion
Lateral cephalogram of an open bite due to rickets.

The open bite is a symptom of a severe skeletal dysplasia with disharmonies in the vertical development. The tongue dysfunction is an adaptation to the skeletal and dentoalveolar morphology.

373 Open bite due to rickets
This enamel hypoplasia of the upper and lower anterior teeth as well as of the first molars results from a vitamin D deficiency which occured at the age of about 1 year.

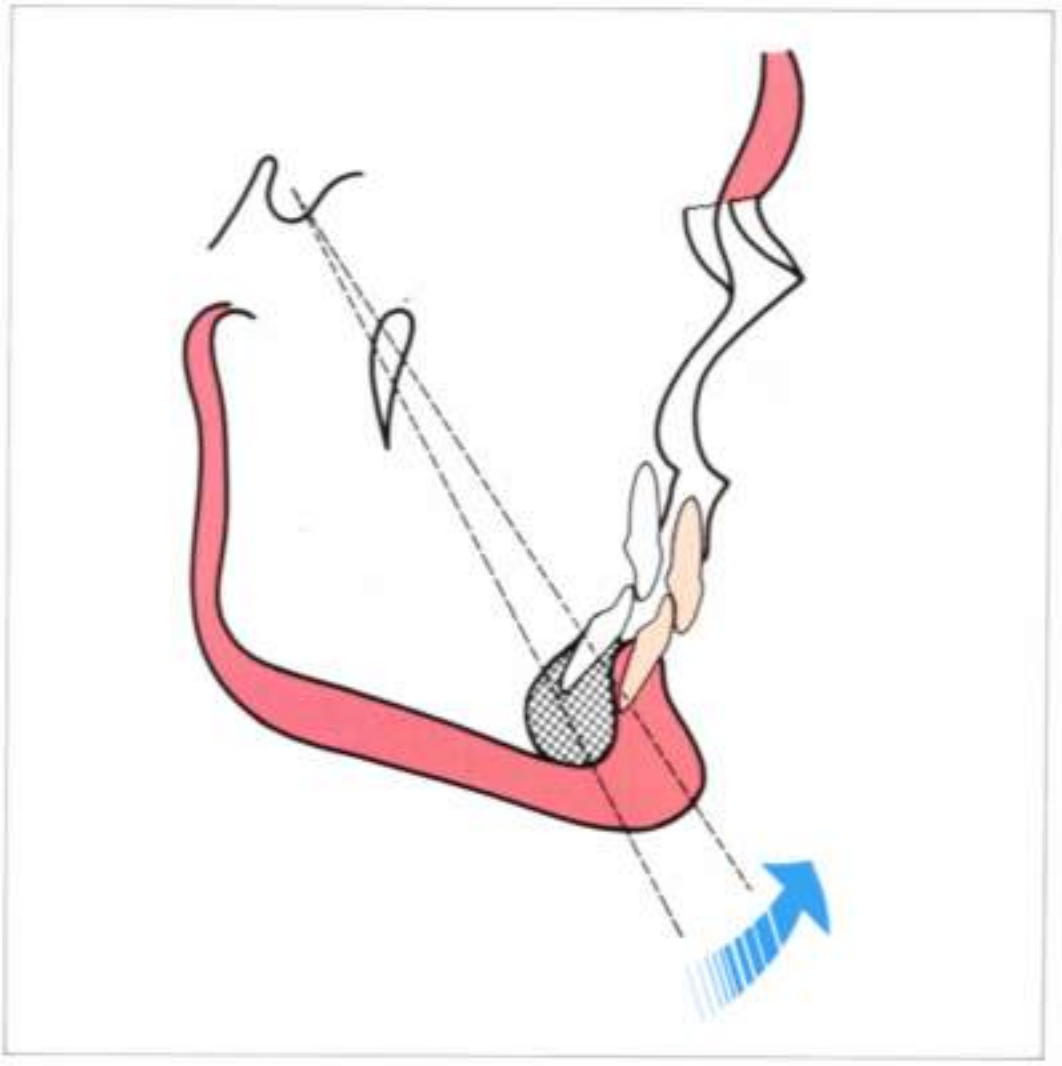
The skeletal and dentoalveolar open bite is aggravated by the adaptive tongue dysfunction.

Configuration of the Craniofacial Skeleton and Dysfunctions

The morphology of the facial skeleton (Figs. 374, 375) and the effects of tongue-thrusting are correlated to a certain degree.

Whereas a horizontal growth pattern in conjunction with tongue-thrust usually results in a bimaxillary dental protrusion (Figs. 376–378); in a vertical growth pattern with tongue-thrust the lower incisors are often in lingual inclination (Figs. 379–381).

From the differential diagnostic point of view, it is important to clarify both the skeletal relationships and the tongue dysfunction in order to localize the results of the abnormal tongue functioning.



374 Horizontal growth pattern
Schematic illustration of the morphologic relationships on the cephalogram in case of a growth-related upward and forward rotation of the mandible.

The dashed line represents the Y-axis.

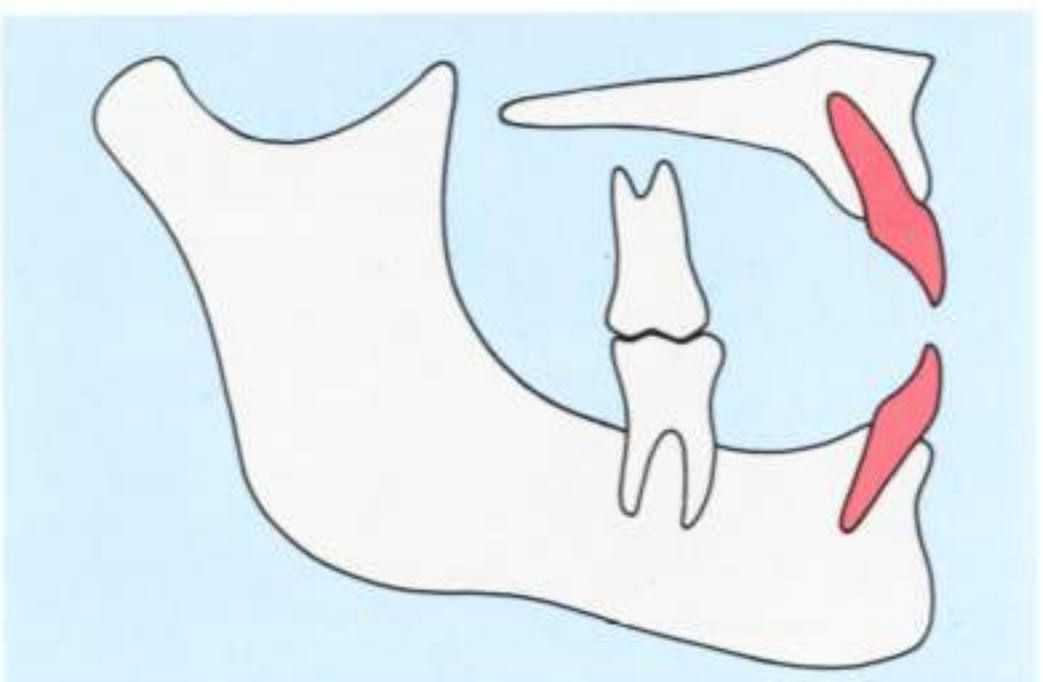
375 Vertical growth pattern
Schematic illustration of the morphologic relationships on the cephalogram in case of mandibular downward and backward rotation during growth.

Horizontal growth pattern associated with anterior tongue dysfunction

376 Clinical picture
In most cases with this type of growth pattern, tongue-thrust causes bimaxillary dental protrusion, i.e. labial tipping of upper and lower anterior teeth.

377 Lateral cephalogram
Cephalometric radiograph of the craniofacial relationships.
Same patient as in Fig. 376.

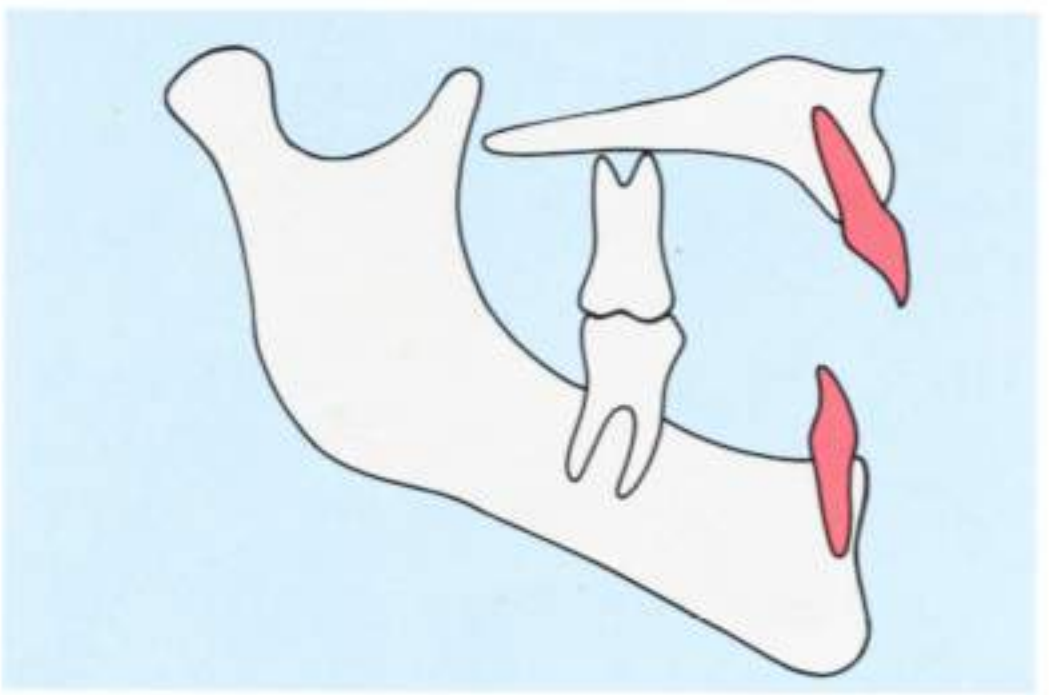
378 Schematic view
Schematic illustration of the incisor relationships in a case with an anterior open bite, tongue-thrust, and horizontal growth pattern.



Vertical growth pattern associated with anterior tongue dysfunction

379 Clinical picture
In cases with this type of growth pattern, tongue-thrust tends to tip the upper incisors to the labial and the lower incisors to the lingual.

380 Lateral cephalogram
Cephalometric radiograph of the craniofacial relationships.
Same patient as in Fig. 379.



381 Schematic view
Schematic illustration of the incisor relationships in a case with an anterior open bite, tongue-thrust, and vertical growth pattern (overeruption of posterior teeth and steeper than normal mandibular plane).

Methods of Examination

Various methods can be used to examine tongue dysfunctions. The different types of clinical examination are: electronic recordings, electromyographic examination, recordings of the pressure exerted by the tongue intraorally, roentgenocephalometric analysis, cineradiographic, palatographic, and neurophysiologic examinations.

The position and size of the tongue in relation to the available space can be assessed using roentgenographic cephalometrics (Figs. 389–391).

However, in most orthodontic cases, registering the position of the tongue is more important than determining its size.

Palatography involves recording the contact surfaces of the tongue with the palate and teeth while the patient produces speech sounds or performs certain tongue functions (Fig. 382). A palatogram is an illustration of these contact areas (Figs. 383–388).

382 Palatographic examination
A thin, uniform layer of contrasting, precise impression material is applied to the patient's tongue with a spatula.

Once the consonant has been pronounced or the tongue movement carried out (e.g. swallowing), the palatogram can be documented photographically using a surface mirror.

Palatogram during the pronunciation of "S"

383 Accurate pronunciation of the "S"
During articulation, the mandible is lowered slightly and pushed forwards. The tongue rests on the teeth and the alveolar processes, and a groove is formed in the center through which the air stream is directed onto the central incisors.

384 Interdental sigmatism (lisping)
During this defective pronunciation of the "S" sound, the tongue is usually protruded and clearly visible between the anterior teeth.

385 Palatal sigmatism
This abnormal pronunciation is caused by an unphysiologic friction noise between tongue and hard palate.

386 Lateral sigmatism on the left side
The tongue rests on the anterior teeth. The column of air escapes on the left side.

387 Bilateral sigmatism
Palatogram of this type of defective articulation in a patient with microglossia.

388 Sigmatism due to lateroflexion to the left side
During this inaccurate formation of the "S" sound, the tip of the tongue is raised too high and rests on the upper incisors.

The tip of the tongue deviates to the left of the midline and the air stream is forced laterally.

Metric evaluation of tongue posture

389 Assessment of tongue position on the lateral cephalogram

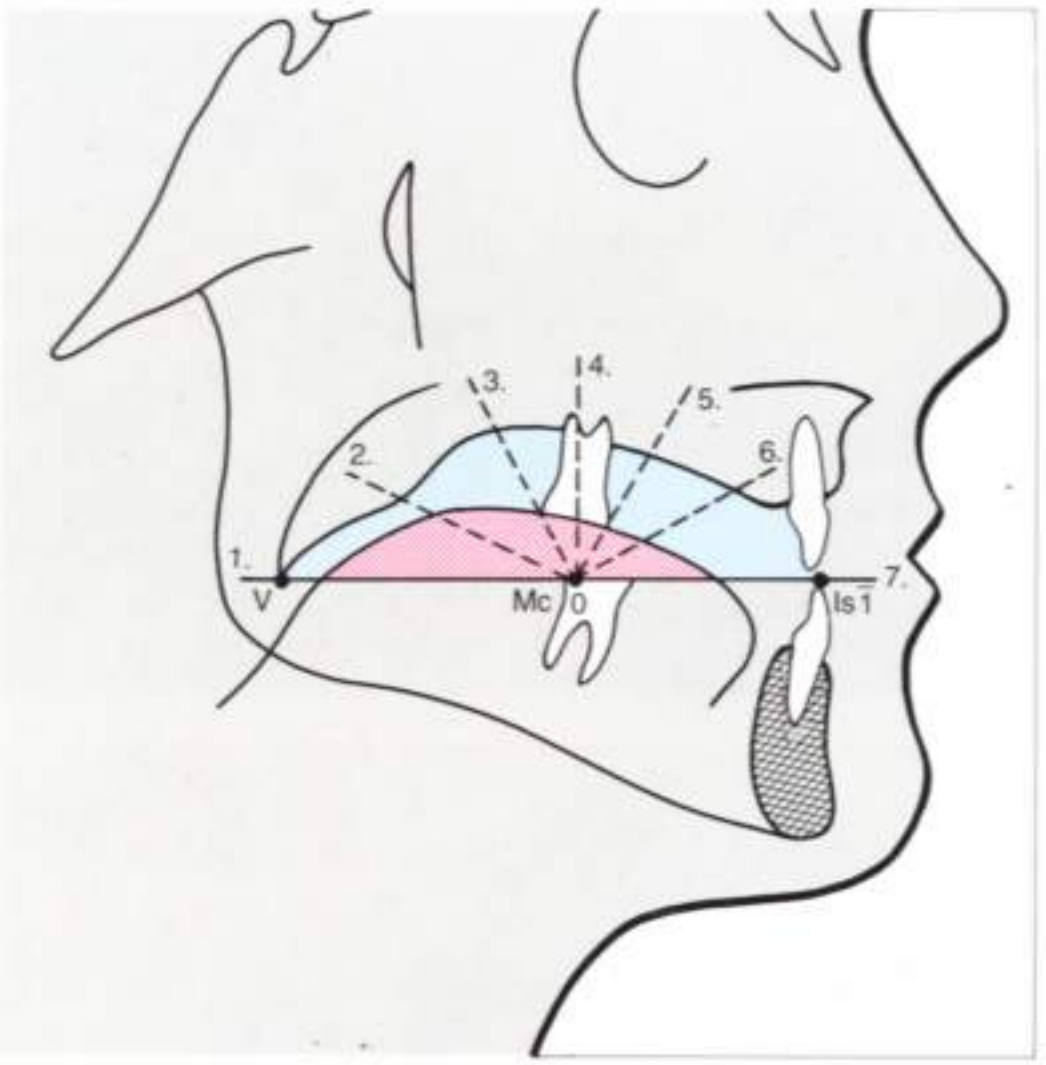
Is $\overline{1}$ = Incisal edge of the lower central incisor.

M_c = Cervical distal third of the last erupted molar.

V = The most inferior point of the uvula, respectively its projection on the reference line (connecting line between Is $\overline{1}$ and M_c).

0 = midpoint on the reference line between Is $\overline{1}$ and V.

A line is drawn through 0, perpendicular to the horizontal baseline, and extended to the palate. A further four lines are drawn, at 30° to each other, resulting in a total of seven lines.

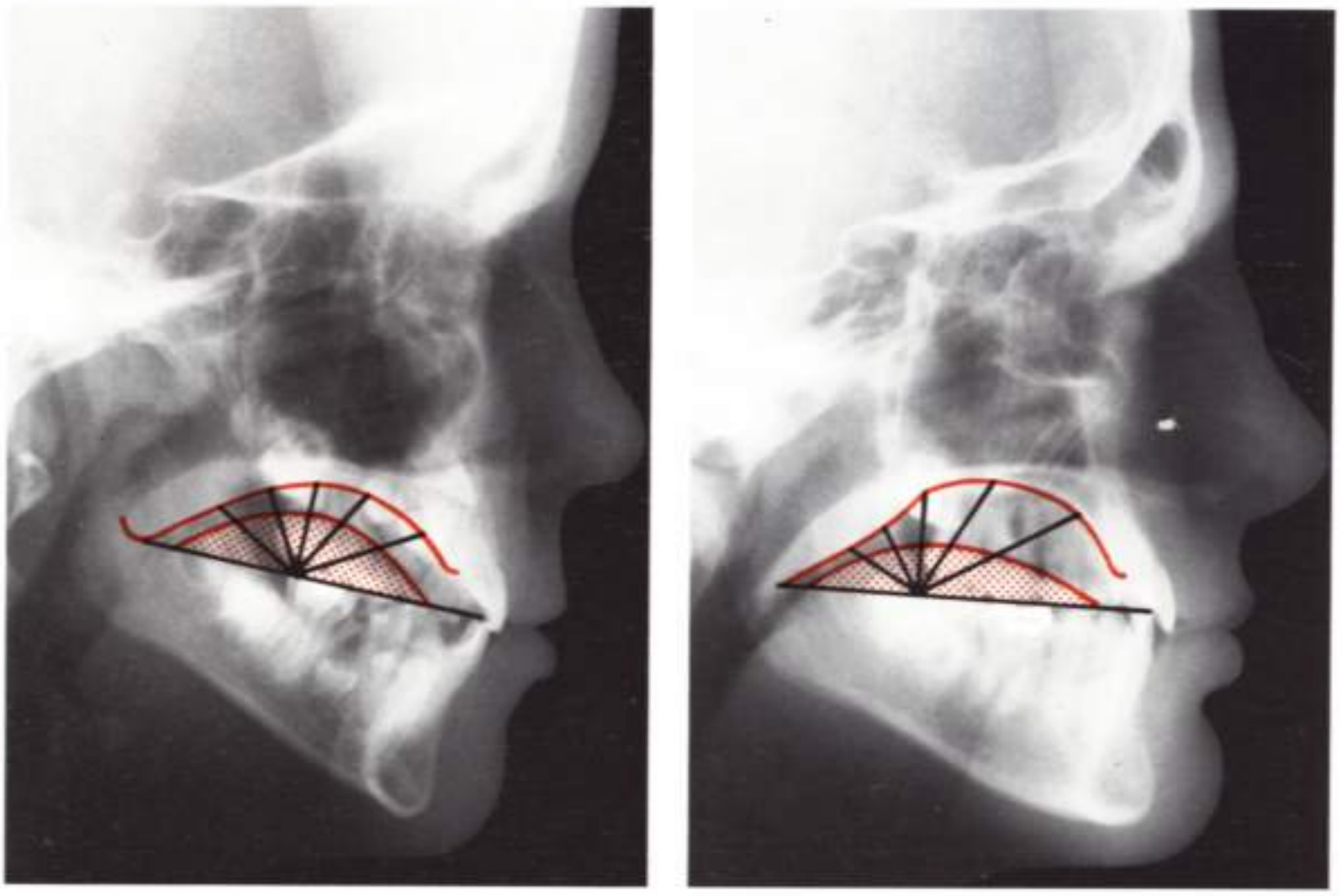


390 Tracing of the analysis on the lateral cephalogram

Marking of the contours of the bony palate and dorsum of the tongue. Horizontal and vertical reference lines for metric evaluation are illustrated.

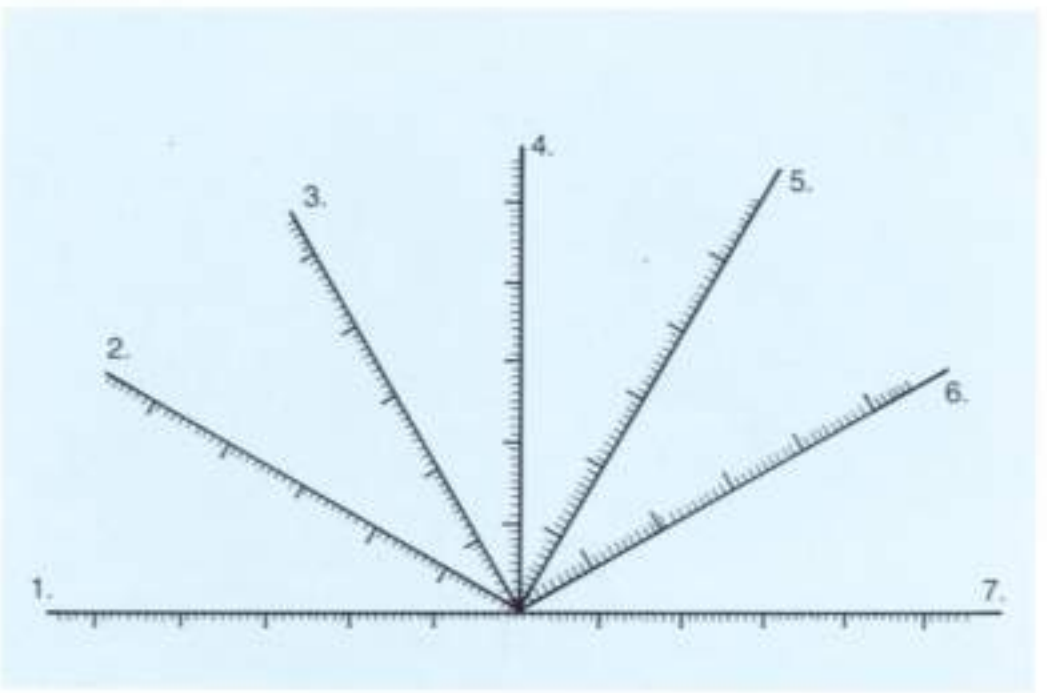
Left: The morphologic relationships in case of a retracted, elevated tongue.

Right: Relationships in case of a downward forward tongue-posture.



391 Template for metric analysis of tongue position

Transparent plastic template with an inscribed millimeter scale for analyzing the position of the tongue on the lateral cephalogram. The template is oriented on the point 0 shown in Fig. 389.



Lip Dysfunctions

The etiology of lip dysfunctions is similar to that of tongue habits and is assessed in relation to the configuration and functioning of the lips.

Configuration of the Lips

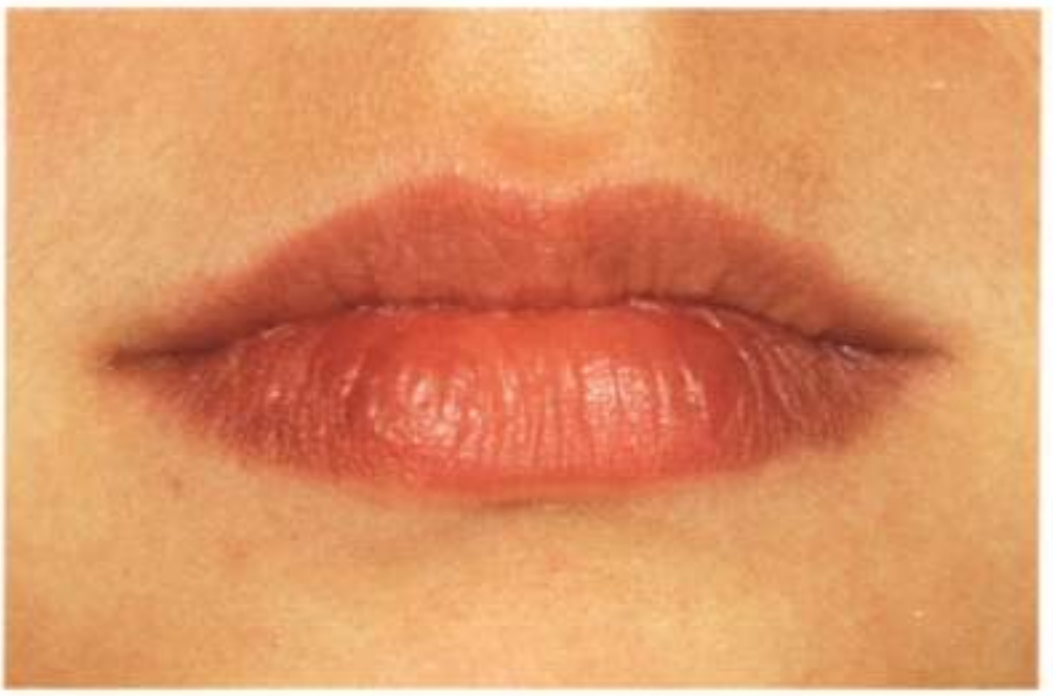
The configuration of the lips differs a great deal. Of the many classifications, the following is the simplest and most suited grouping for daily practice:

Competent lips. Lips which are in slight contact when the musculature is relaxed (Fig. 392).

Incompetent lips. Anatomically short lips which do not touch when the musculature is relaxed. Lip seal is only achieved by active contraction of the orbicularis oris and the mentalis muscles (Figs. 393, 394).

Potentially incompetent lips. The protruding upper incisors prevent the lip closure. Otherwise, the lips are developed normally (Figs. 395, 396).

Everted lips. These are hypertrophied lips with redundant tissue but weak muscular tonicity (Figs. 397, 398).



392 Competent lips
Frontal and profile views. The lips are in contact when the musculature is relaxed.

Incompetent lips

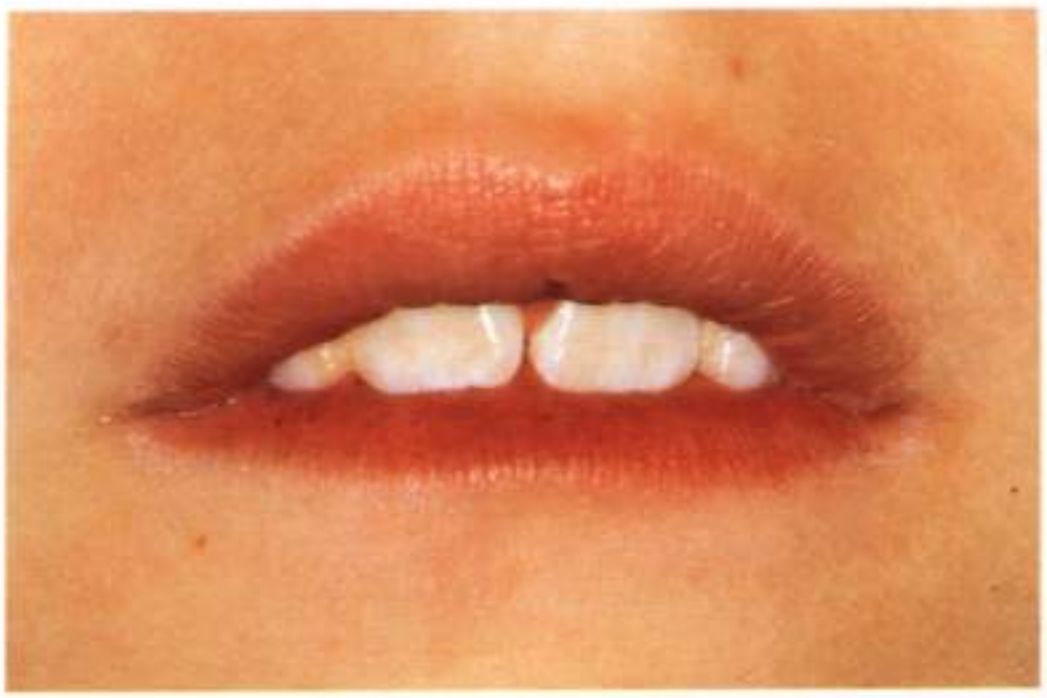
393 Habitual lip posture
Anatomically short lips with a wide gap between the upper and lower lip in relaxed position.

394 Consciously closed lips
Incompetent lips can only be closed by increased contraction of the orbicularis oris and mentalis muscles.

Potentially incompetent lips

395 Habitual lip posture
The upper incisors are labially tipped and their incisal margins interpose between the lips preventing the normal lip seal.

Right: For sealing the oral cavity the tip of the tongue is in contact with the lower lip.



396 Consciously closed lips
Lip contact is achieved without increased contraction of the perioral musculature.

Everted lips

397 Habitual lip posture
Frontal and profile views with the lips closed.

398 Lateral cephalogram
Due to the weak tonicity of the lip musculature, these patients often exhibit bimaxillary dental protrusion (labial inclination of both upper and lower incisors).

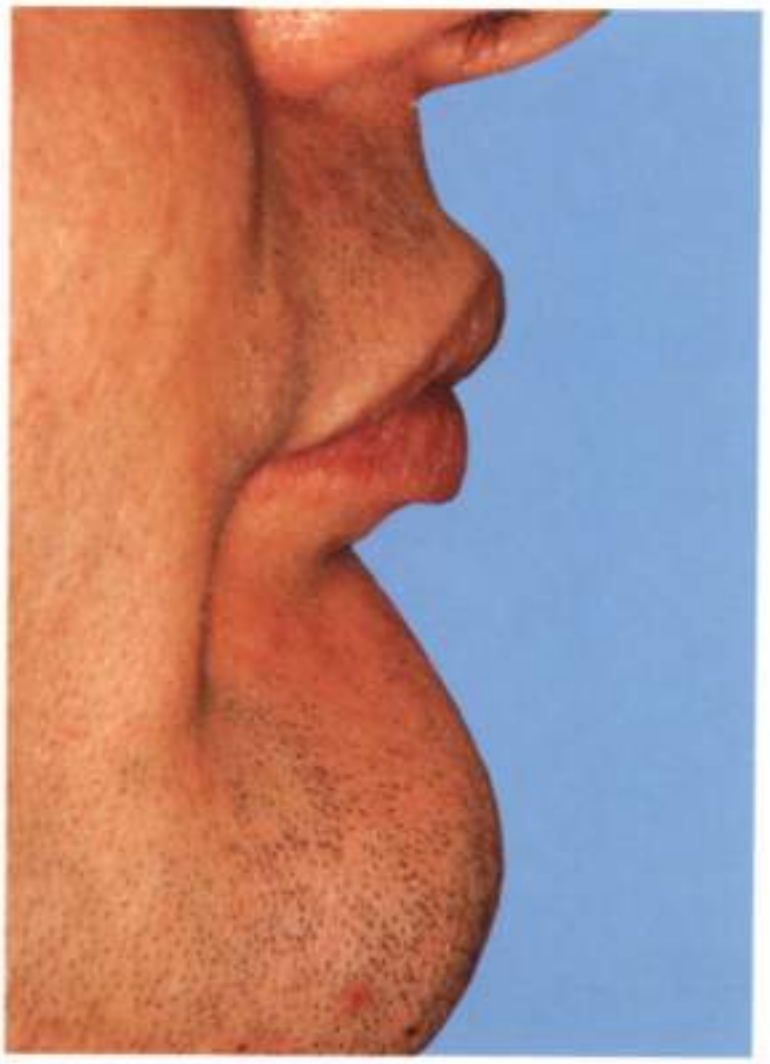
Lip Habits

The various habits of the lips can be divided into *lip-sucking* (Fig. 399), *lip-thrust* (Fig. 400), and *lip insufficiency* (Fig. 393).

Lip dysfunctions can be observed while the patient is speaking and swallowing. The lower lip often shows variations of dysfunction with regard to the tip of the tongue. The lower lip and the tip of the tongue are often in contact. In such cases, the lower lip is sucked in and pressed against the tip of the tongue. Any lip activity during swallowing – apart from closing the lips – is unphysiologic and a symptom of an orofacial dysfunction. Visual evidence of mentalis muscle activity is also abnormal.

399 Lip-sucking
Extraoral findings. The lower lip is positioned behind the upper incisors. In many patients, malpositioning of the lips occurs in conjunction with hyperactivity of the mentalis muscle.

Right: The lateral cephalogram indicates that the dysfunction of the lower lip causes further protrusion of the upper incisors and impedes the forward development of the lower anterior alveolar process.



400 Lip-thrust
Characteristic profile of the lower third of the face in a case with hyperactivity of the mentalis muscle.

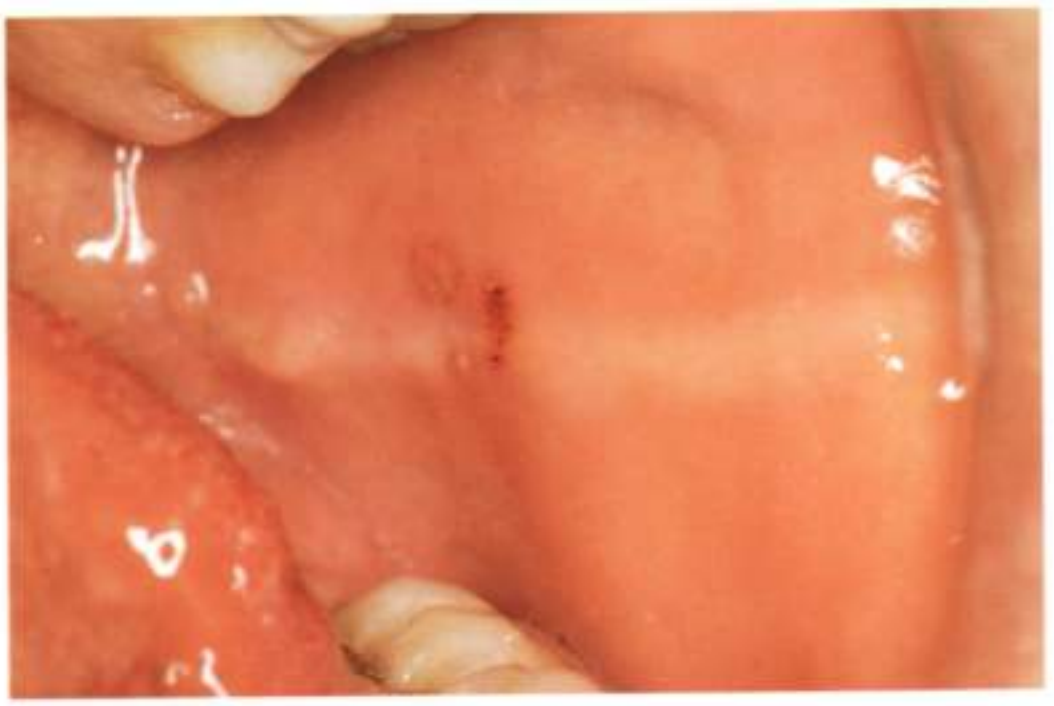
Right: In many patients, this type of lip habit is combined with lingual inclination of the incisors.

Cheek Dysfunctions

In case of cheek-sucking (Fig. 401) or cheek-biting (Fig. 402) the soft tissues are interposed between the occlusal surfaces of the teeth, which promotes the formation of a lateral open bite or a deep overbite.

Increased lateral pressure by the cheek musculature on, for example, the mandible impedes the transverse development of the jaw. This type of cheek dysfunction is common in cases with buccal nonocclusion (Fig. 403).

401 Cheek dysfunction
Extraoral findings in a case with hyperfunction of buccinator muscle and cheek-sucking.



402 Cheek-biting
This female patient shows a weal-like horizontal swelling of the buccal mucosa caused by the dysfunction.

403 Cheek dysfunction and malocclusion
Buccal nonocclusion in the deciduous dentition combined with a cheek dysfunction.

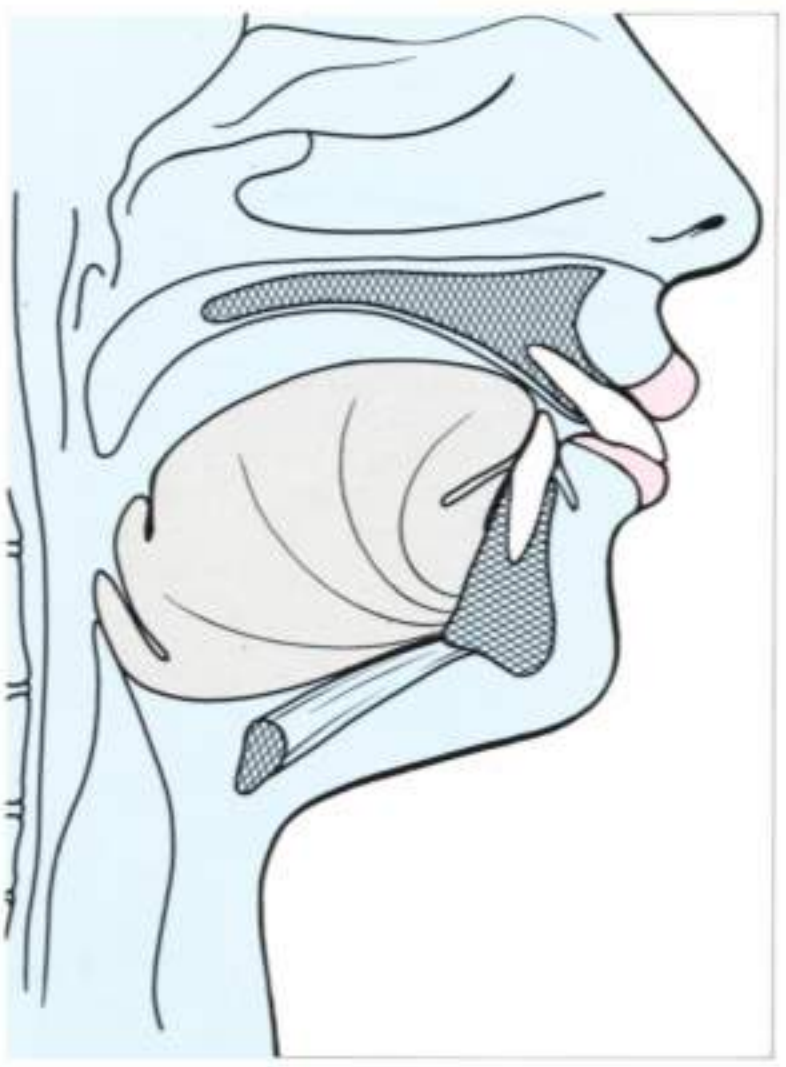
Hyperactivity of Mentalis Muscle

The deep mentolabial sulcus (Fig. 404) is characteristic of a hyperactive mentalis muscle. This habitual pattern of muscle behavior impedes the forward development of the anterior alveolar process in the mandible (Fig. 405).

The abnormal mentalis function often occurs together with lip-sucking or lip-thrust (Fig. 403). Cases of hyperactivity of the mentalis muscle which occur in the same family, are usually *hereditary* (Fig. 404). However, this finding may be based on an *imitation* of the dysfunction.

404 Deep mentolabial sulci and hyperactivity of mentalis muscle
Profile view of a female patient with the clinical appearance of the abnormal muscle function.

Right: The same dysfunction is diagnosed in the sister, who is 2 years older.



405 Cephalometric findings in case of hyperfunction of the mentalis muscle and the lower lip
The dentoalveolar location of the Class II malocclusion is characteristic.

Right: The hyperactive mentalis muscle pulls the lower lip upward and rearward and presses it against the lingual surfaces of the upper incisors. The upper lip remains relatively motionless. The normal lip seal is disturbed and the tongue displaced downward.

This type of soft-tissue morphology aggravates the dentoalveolar malocclusion.

Mouth-Breathing

The mode of respiration is examined to establish whether the nasal breathing is impeded or not. Chronically disturbed nasal respiration represents a dysfunction of the orofacial musculature; it can restrict development of the dentition and hinders the orthodontic treatment. The following clinical findings are typical of patients with oronasal respiration: a high palate, persisting "tooth germ position" of the upper incisors, narrowness of the upper arch, cross-bite, often accompanied by poor oral hygiene and hyperplasia of the gingiva (Figs. 407, 408). The extraoral appearance of these patients is often conspicuous, and is termed *"adenoid facies"* (Fig. 406).

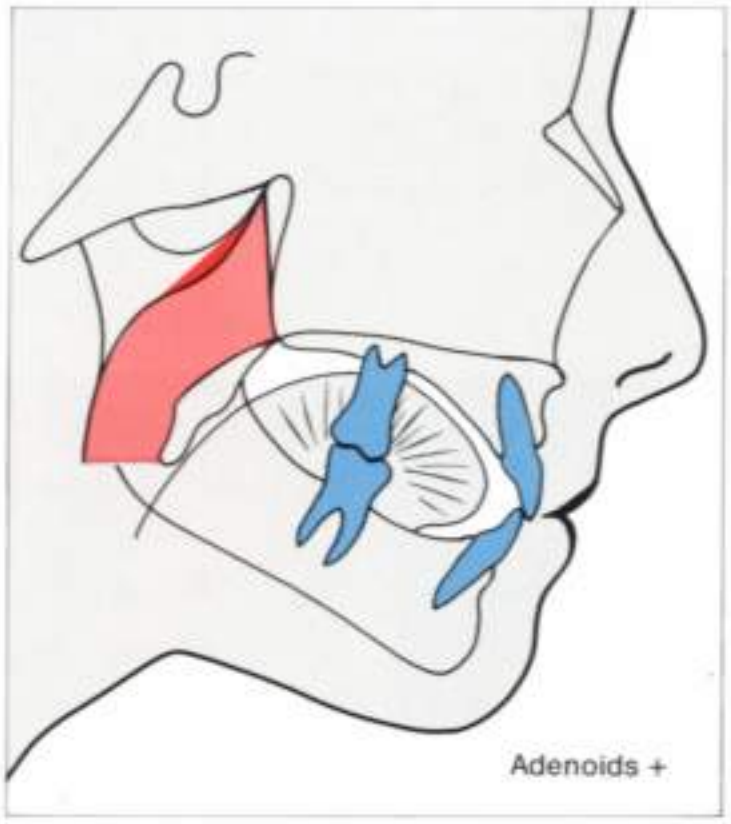
406 "Adenoid facies"
Frontal and profile views of a 6-year-old female patient with chronically restricted nasal respiratory function.

407 Occlusal and dental findings in case of oronasal respiration
The upper jaw is markedly constricted, the "tooth germ position" of the upper incisors has persisted, the mandibular arch is well formed. Due to the incongruence in arch width a bilateral cross-bite exists.

408 Configuration of the maxilla in oronasal respiration
The high palate and narrow upper arch are characteristic features.

Pattern of Facial Morphology

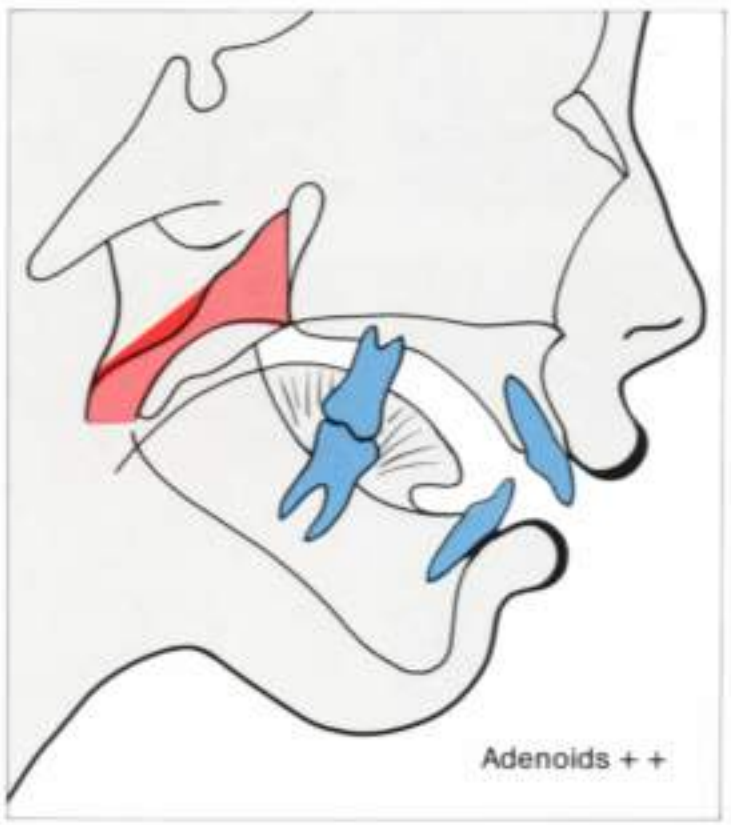
The configuration of the facial skeleton and oral respiration are correlated to a certain degree. Impeded nasal breathing shows a higher frequency in facial types with vertical growth tendency. Proliferation of the adenoids is more common and more pronounced in patients with oronasal respiration. The incidence of hypertrophied tonsils is also increased in this group (Figs. 409–411).



Classification of the adenoids on the lateral cephalogram

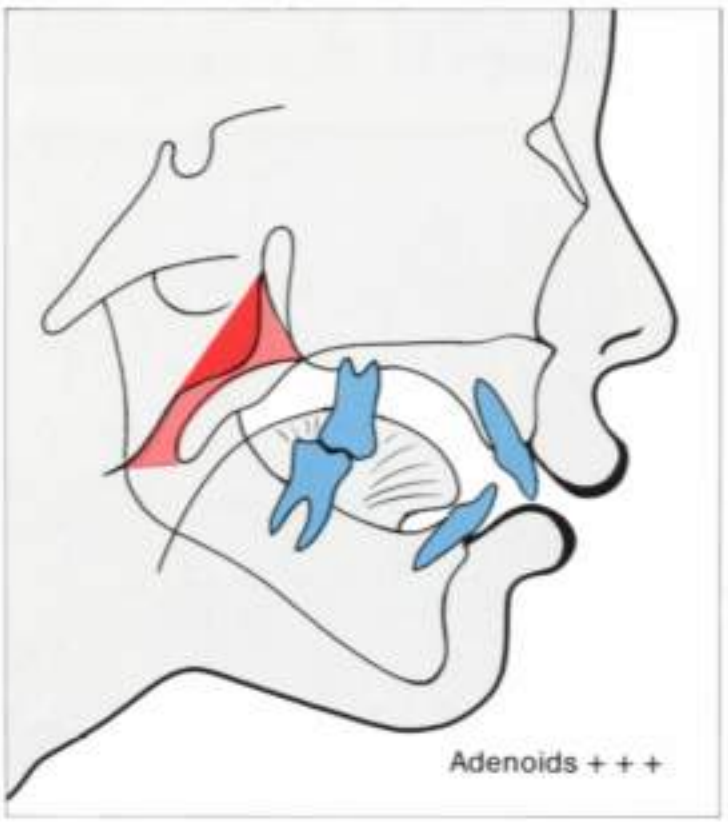
409 Small-sized adenoids (+)
The radiographic images of the adenoids on the lateral cephalogram appear as a slight curvature on the upper rear wall of the nasopharynx.

Left: Schematic illustration of the morphological relationships.



410 Medium-sized adenoids (++)
Noticeable proliferation of lymphoid tissue on the upper rear wall of the nasopharynx, which occupies approximately half of the visible pneumatic cavity in the epipharynx.

Left: Schematic illustration of the relationships.



411 Large-sized adenoids (+++)
The lymphatic tissue occupies most of the nasopharyngeal pneumatic cavity.

Left: Schematic illustration of the relationships.

Tongue Posture

Two different tongue postures are possible in case of oronasal respiration:

Type I: The tongue is flat and its tip is behind the lower incisors. This type is often encountered in conjunction with an anterior cross-bite (Figs. 412, 414).

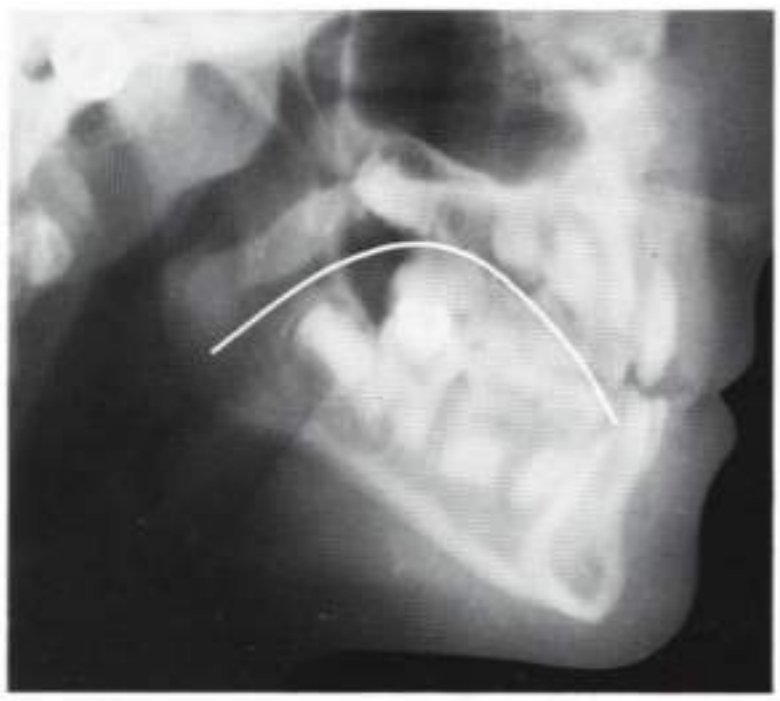
Type II: The tongue is flat and retracted. This type of abnormal tongue posture is common in cases with oral respiration and distoclusion (Fig. 413).

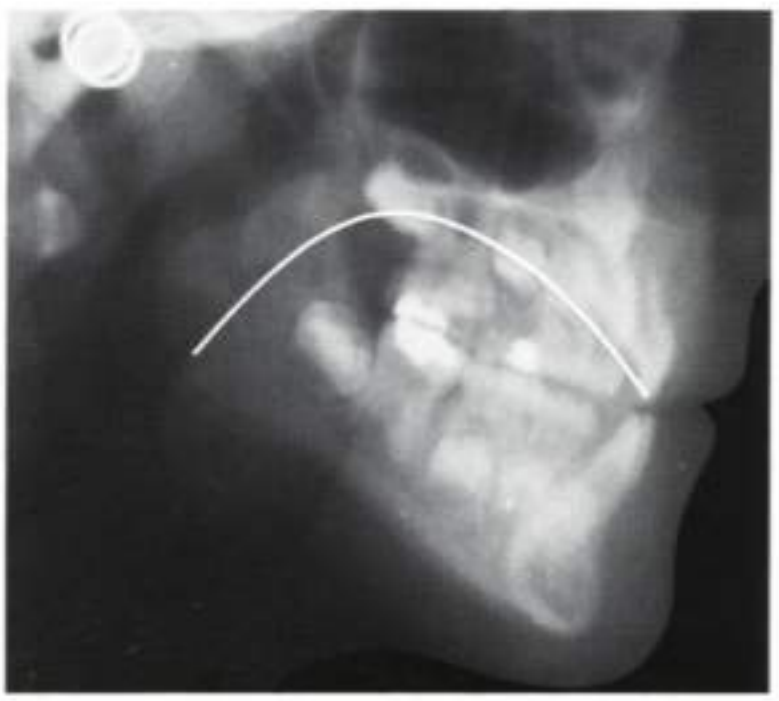
412 Type I tongue position
Class III malocclusion with a flat, protruding tongue posture.

The downward forward position of the tongue has been marked with contrast medium on the lateral cephalogram.

413 Type II tongue position
Class II malocclusion with flat, retracted tongue posture.

The downward backward position of the tongue has been marked with contrast medium.





414 Tongue position and oral respiration
These lateral cephalograms show the position of the tongue in a patient with restricted oral respiration prior to *(left)* and after *(right)* removal of the adenoids.

After ENT surgery and change to nasal breathing the initially flat positioned tongue was raised toward the palate.

Examination of Breathing Mode

The case history (e.g. details regarding recurrent diseases of the upper air passages, sleeping habits) and evaluation of tongue and lip posture as well as lip function, provide certain *keys concerning the breathing mode.*

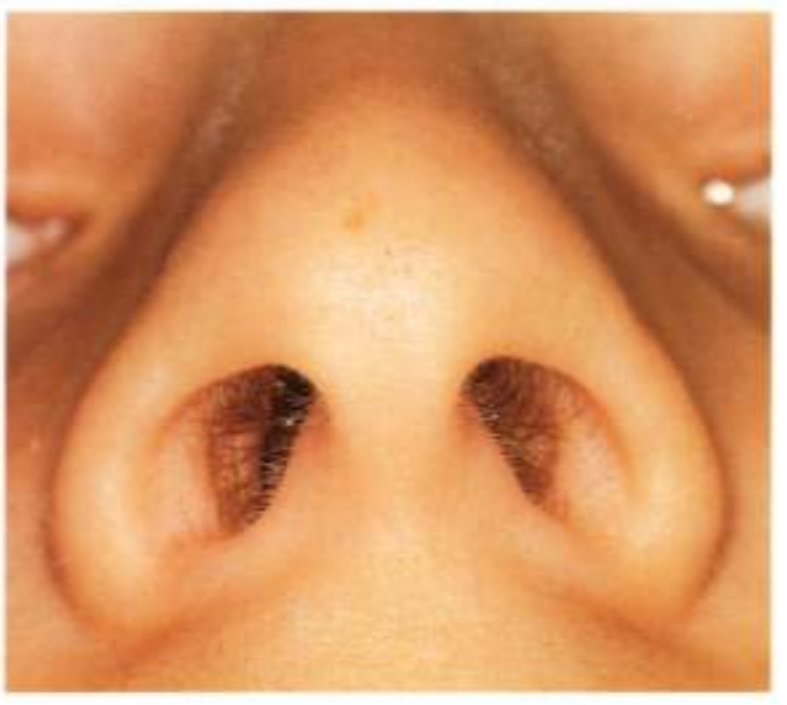
The following are various clinical methods of examination which permit a crude check of the degree of nasal obstruction: the cotton pledget test, the mirror test (Fig. 415), and observation of the nostrils (Fig. 416). When interpreting the findings, it must be taken into account that the respiratory mode is controlled by the *nasal cycle* which changes approximately every 6 hours. This is a physiologic protective mechanism which prevents the nasal membranes from drying out (Eccles, 1978; Masing and Wolf 1969). Due to the nasal cycle, one nasal airway is always more constricted than the other, i.e. an apparent unilaterally obstructed nasal passage during the crude clinical examination is not necessarily a pathologic finding.

415 Mirror test
The mirrors are held in front of both nostrils. In nasal-breathers the mirror will cloud with condensed moisture during expiration as shown on the right.

Examination of alar musculature

416 Nasal respiration
The size and shape of the external nares of a patient with nasal respiration during inspiration *(left)* and expiration *(right).*

The very noticeable changes in the cross-section of the nasal orifices are typical for nasal-breathers.



417 Oronasal respiration
The cross-section of the external nares of a patient with prevailing oral respiration during inhaling *(left)* and exhaling *(right).*

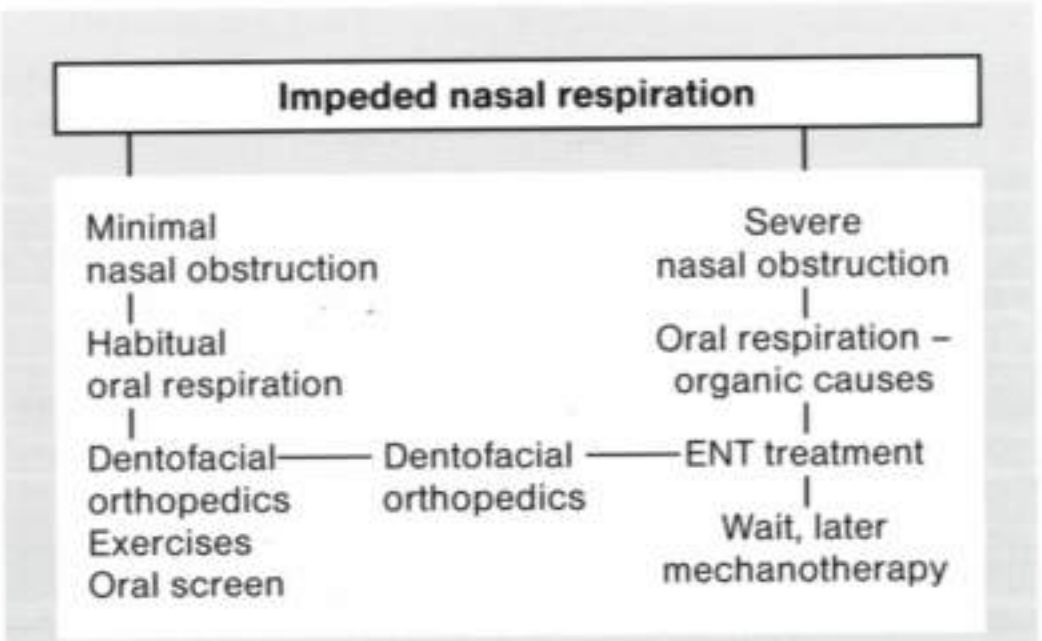
The alar muscles are inactive – nares do not change their size –, which is a clinical feature of increased oral respiration.

Differential Diagnosis

Differential diagnosis must be used to determine whether the problems in nasal respiration are due to an *obstruction of the upper nasal passages* or to *habitual oral respiration* (Fig. 418). In the first case, an operation by an ENT-specialist is indicated; i.e. in the case of allergic rhinopathy, medication should be applied. Should the nose not be obstructed, pre-orthodontic therapy should be carried out to treat the restricted nasal breathing. This may include breathing exercises (Fig. 419) or incorporation of a perforated oral screen (Fig. 420).

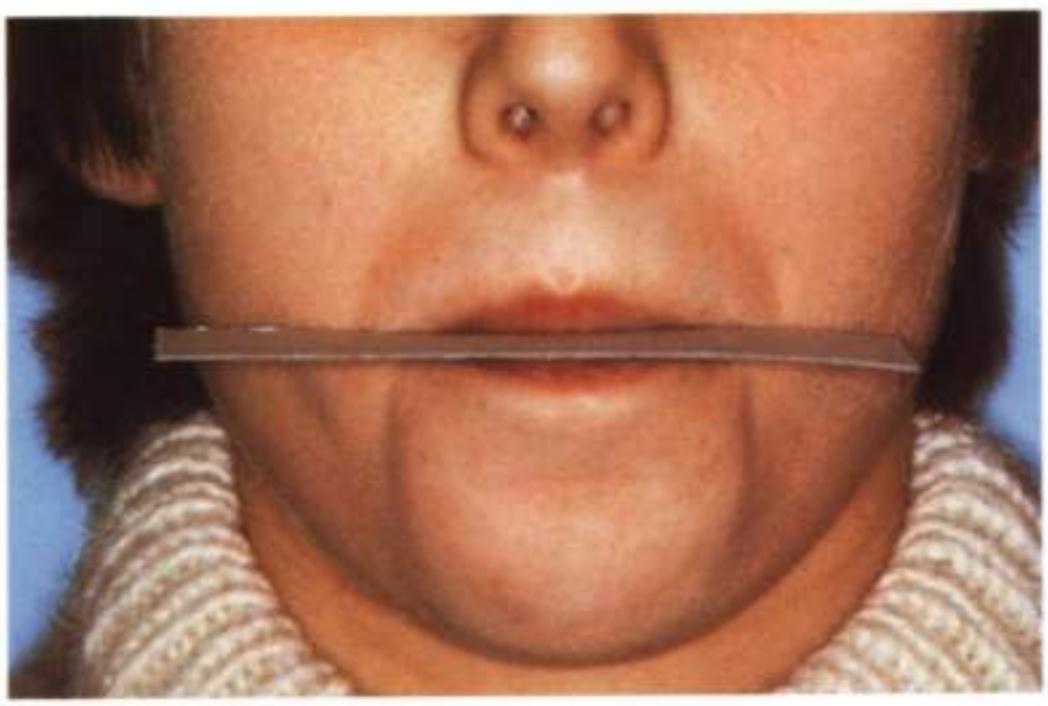
418 Differential diagnosis of restricted nasal respiration
The orthodontic treatment planning for patients with restricted nasal respiration must be related to the diagnosis of the ENT-specialist.

Otorhinologic determination of the *nasal resistance* appears to be an important parameter to assess nasal breathing capacity.



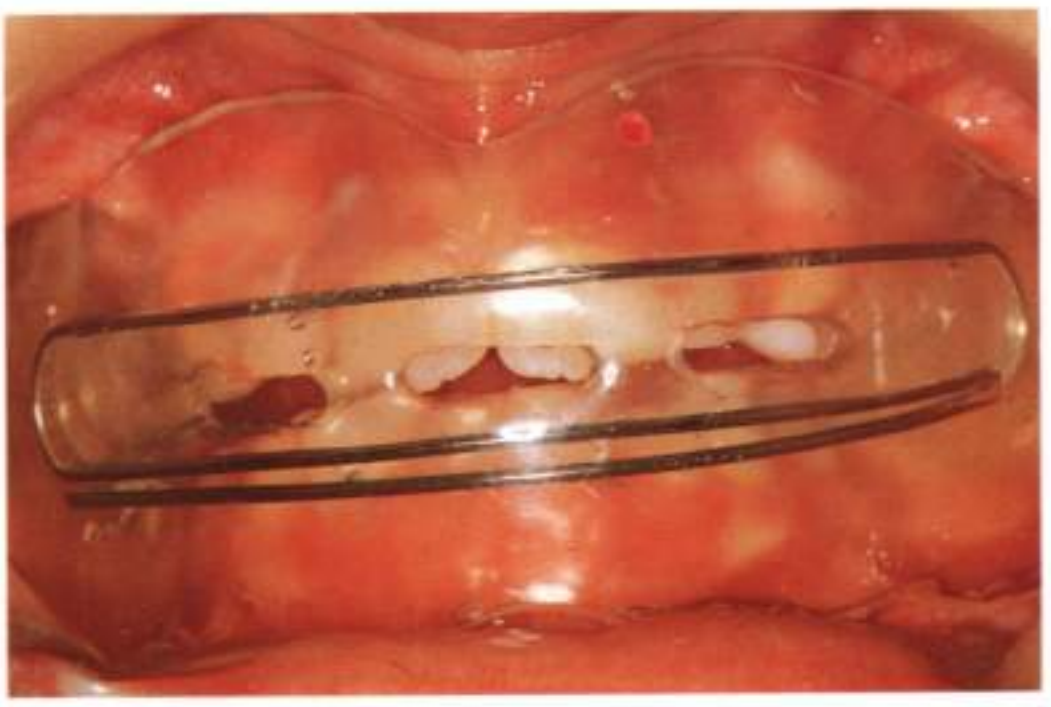
419 Myofunctional exercises for patients with habitual oral respiration
Lip exercises with a piece of cardboard to improve the lip seal are indicated.

Right: The cardboard should be held loosely in a horizontal position with the lips.



420 Changing habitual oral respiration
The custom-made, perforated oral screen is placed in the vestibule.

The air holes in the appliance are sealed off one after the other to convert patients who breathe through their mouth to nasal respiration.



Functional Analysis – Record Sheet

1) Relationship: Rest position – Habitual occlusion

a) *Sagittal*

Habitual occlusion: distal / mesial / edge-to-edge relationship
Rest position: mandible posterior – anterior

b) *Transverse*

Mandibular midline shift
in habitual occlusion: mm
in rest position: mm
maximum jaw opening: mm

c) *Vertical*

Freeway space: normal – large – small

2) Temporomandibular joint

Crepitus: right – left – both sides
Clicking: right – left – both sides
initial – intermediate – terminal – reciprocal

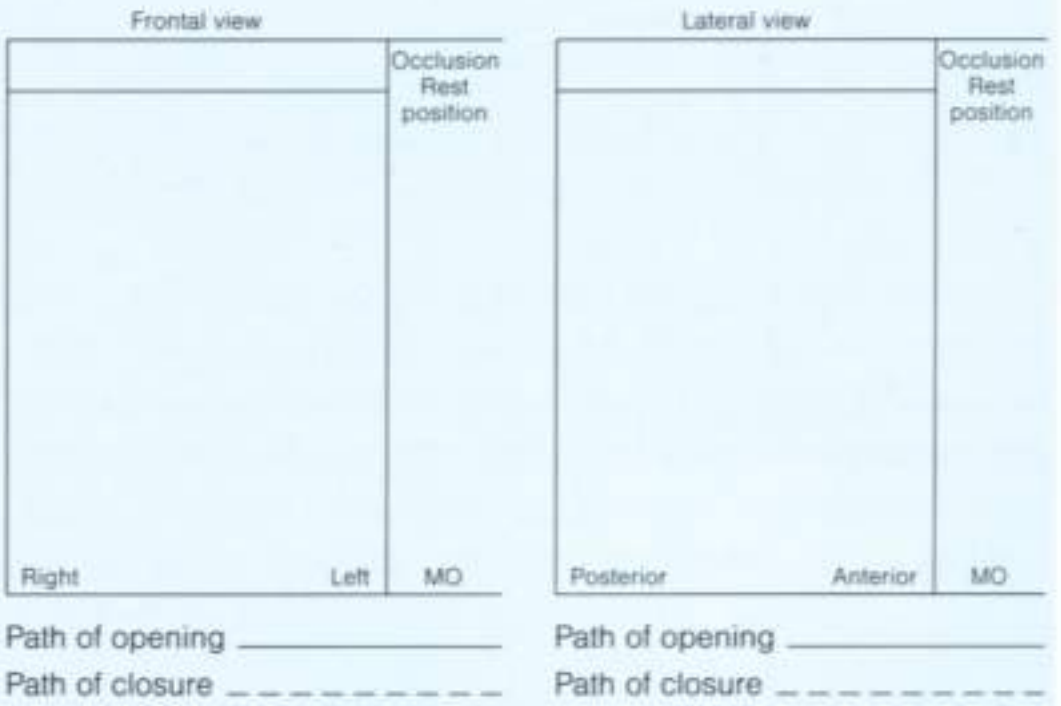
Pressure sensitivity: right / left / both sides

Pressure sensitivity – Musculature: lateral pterygoid right/left
masseter right/left
temporalis right/left
others:

Mandibular mobility:
Maximum interincisal distance: mm
Maximum protrusive movement: mm
Maximum lateral movement: right: mm
left: mm

Deviations
Path of opening / closure
lateral: yes / no
frontal: yes / no

Tooth guided sliding:
Tooth interference at:
Cant of occlusal plane: no / yes right/left
Working side: right/left



3) Dysfunctions

Swallowing pattern: somatic – viscerosomatic – visceral
Tongue dysfunctions: tongue-thrusting – tongue-biting
Lip dysfunctions: lip-thrusting – lip-biting
Speech defects: yes / no Referred to speech therapist on:
Findings of speech therapist from:
Parafunctions: yes / no Type: Diornal
Nocturnal

Respiration
Normal nasal respiration: yes / no
Oral respiration: habitual / anatomical
Referred to ENT-specialist on:
Findings of ENT-specialist from:

Radiologic Examination

Radiologic examination is absolutely essential in orthodontic diagnosis. Most patients are young. In clinical practice, the type and number of radiographs should, therefore, subject the patient to as little radiation exposure as possible while providing maximal information at the same time. In some cases, depending on the nature of the problems, a routine examination may necessitate supplemental radiographs. Broadly, there are two kinds of radiograph required for an orthodontic diagnosis. The first are those taken to provide information regarding the *condition of the teeth*, the periodontium, and the bony structures. The objective of the others is an assessment of the malocclusion in relation to the facial skeletal structure. Radiographs of the *hands* and *temporomandibular joints* are not among the routine requirements of orthodontic diagnosis. It is only necessary to take radiographs of the temporomandibular joints in those cases where TMJ symptoms of dysfunction are either present or where changes are reasonably suspected, that are not seen clearly on the panoramic view.

Dental Condition

- Panoramic view
- Enlarged panoramic view
- Periapical view; small intraoral film
- Occlusal view
- Mental spine (genial tubercle) view

Panoramic view. For orthodontic diagnosis this is superior to all other radiographic methods. Not only does it provide in one single film a total survey of the dental status and adjacent bony structures of both jaws, but at the same time it also includes the temporomandibular joints. It involves the least exposure to radiation. A disadvantage of this rotary laminographic technique is a possible distortion in the anterior region. Some cases will, therefore, require supplementary radiographs, such as an enlarged panoramic view or periapical view.

Enlarged panoramic view. Its advantage is the accurate imaging of the region of the anterior teeth; its disadvantage is distortion in the posterior region.

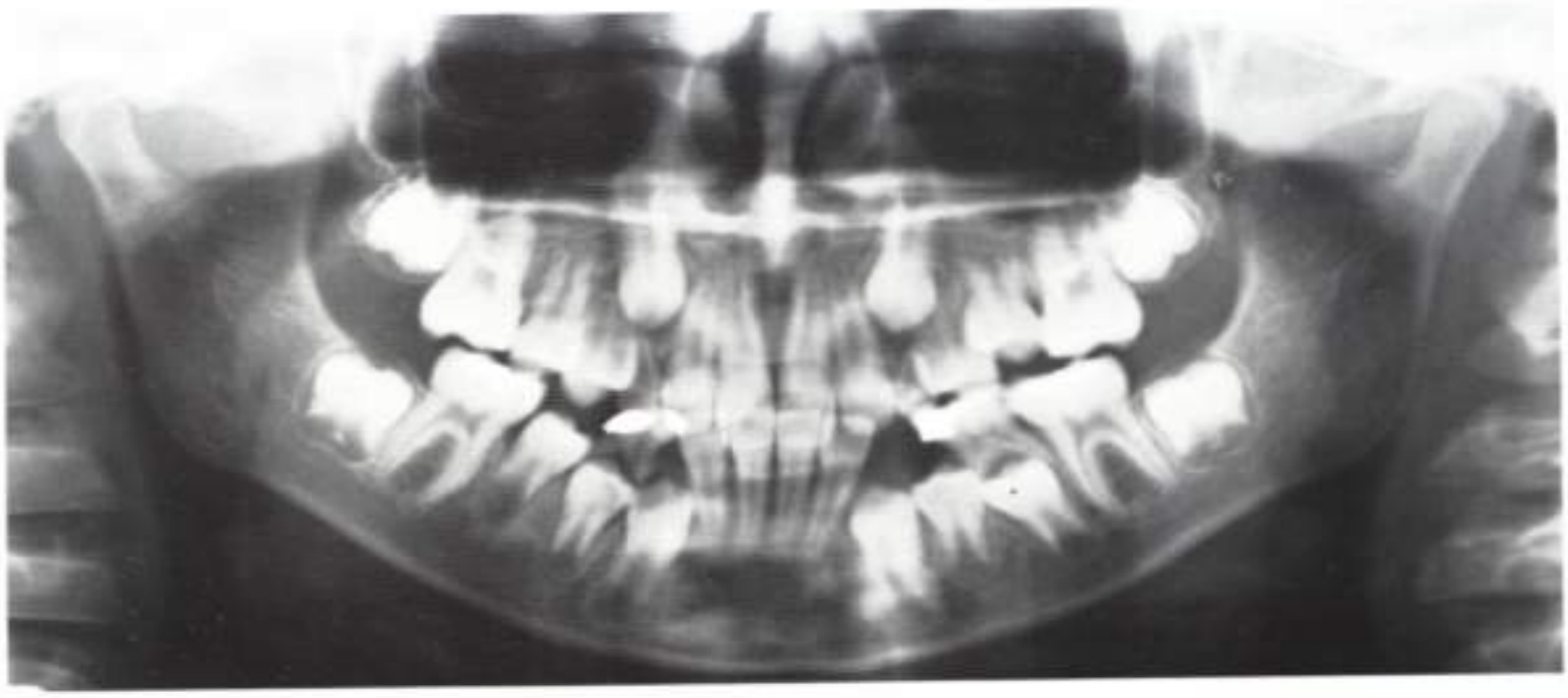
Periapical view (small intraoral film). A full series of intraoral radiographs (10 to 16 films) is required for assessment of the periodontal state in adults. Otherwise periapical films are only indicated where the panoramic view suggests possible pathologic conditions (e.g. congenitally missing teeth or malposed tooth germs) (Figs. 428, 429).

Occlusal view. This radiograph is indicated as a supplementary projection to determine the three-dimensional location of malposed unerupted teeth. The oblique occlusal film is an alternative view to determine the width of as yet unerupted permanent teeth in the mixed dentition.

Mental spine (genial tubercle) view. This is an occlusal view of the anterior section of the mandible to determine its midline (Figs. 431, 432).

421 Panoramic view
Panoramic view of a 9-year-old boy with an atypical sequence of eruption of permanent teeth after premature extraction of primary teeth in the lateral segments.

The panoramic radiograph gives a survey of the entire dental condition and abnormalities of the mixed dentition in one single exposure.



422 Chart for radiologic evaluation of dental conditions
The panoramic view should be systematically analyzed according to a predetermined chart. By this means, the risk of serious misdiagnoses during the clinical routine, which might affect the orthodontic treatment is minimized.

Radiologic findings:

Hypoplasia:	Path. lesions at crown/apex.: .....
Impacted teeth:	Supernumerary teeth: .....
Narrow tooth germ position:	Ectopic tooth germs: .....
Teeth not worth saving:	Third molars: .....
Root canal fillings:	Extracted permanent teeth: .....
Large restorations:	Root fragments: .....
Root resorption:	Overretained primary teeth: .....
Path. periodontal ligament space:	Path. root formations: .....
Bone loss:	Trabecular pattern: .....
Atypical sequence of eruption:	Bony pockets: .....

Other: .....
.....
.....

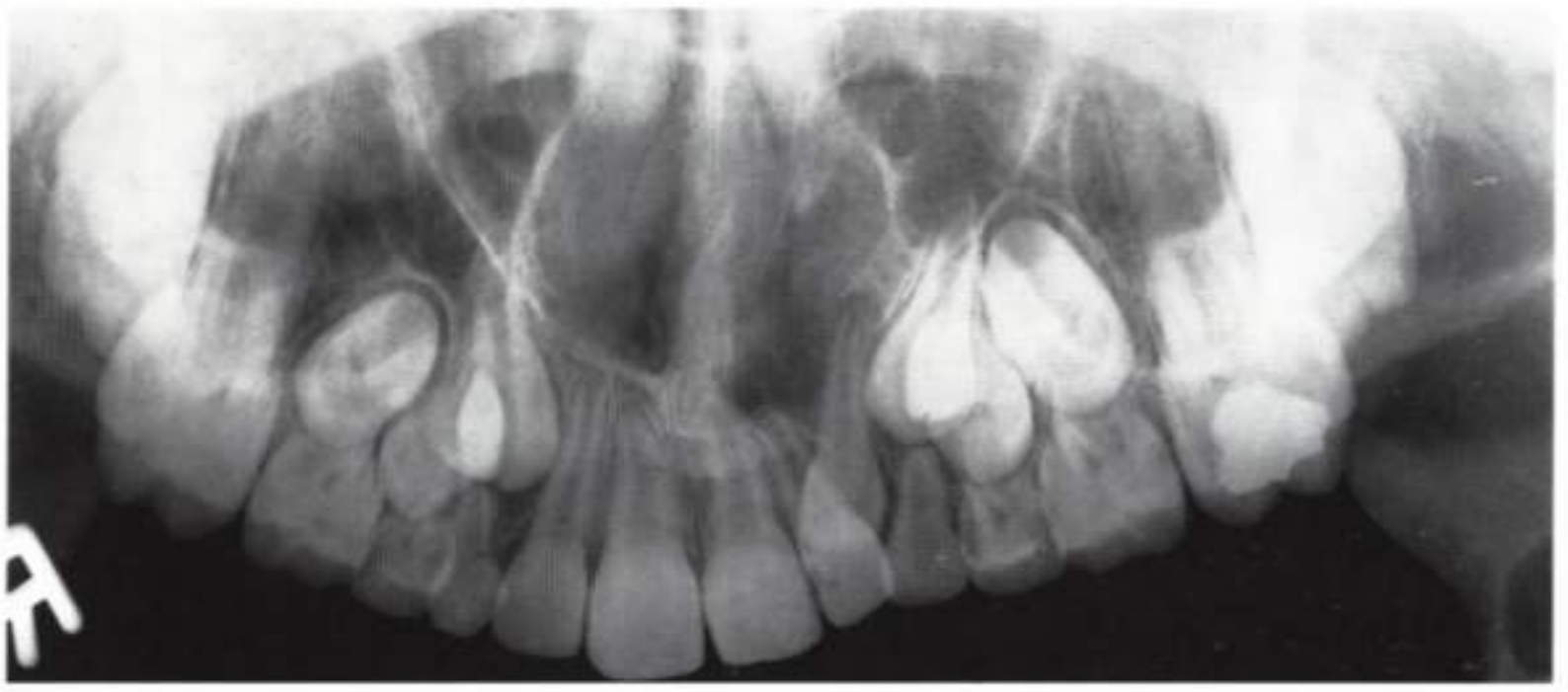
423 Panoramic view and evaluation of temporomandibular joint
Condition 2 years after condylar neck fracture of the left TMJ in an 8-year-old girl.

While only crude assessments can be made from the panoramic view as regards the TMJ, some information relating to fractures can nevertheless be obtained from it. The condylar shape can also be judged from this view. However a detailed examination of the joint space or the position of the condyle within the glenoid fossa is not possible with this screening film.

424 Panoramic view and condition of anterior teeth
Right: Panoramic view of a 10-year-old boy who sustained trauma to the primary teeth in the upper anterior region at the age of 5 years.

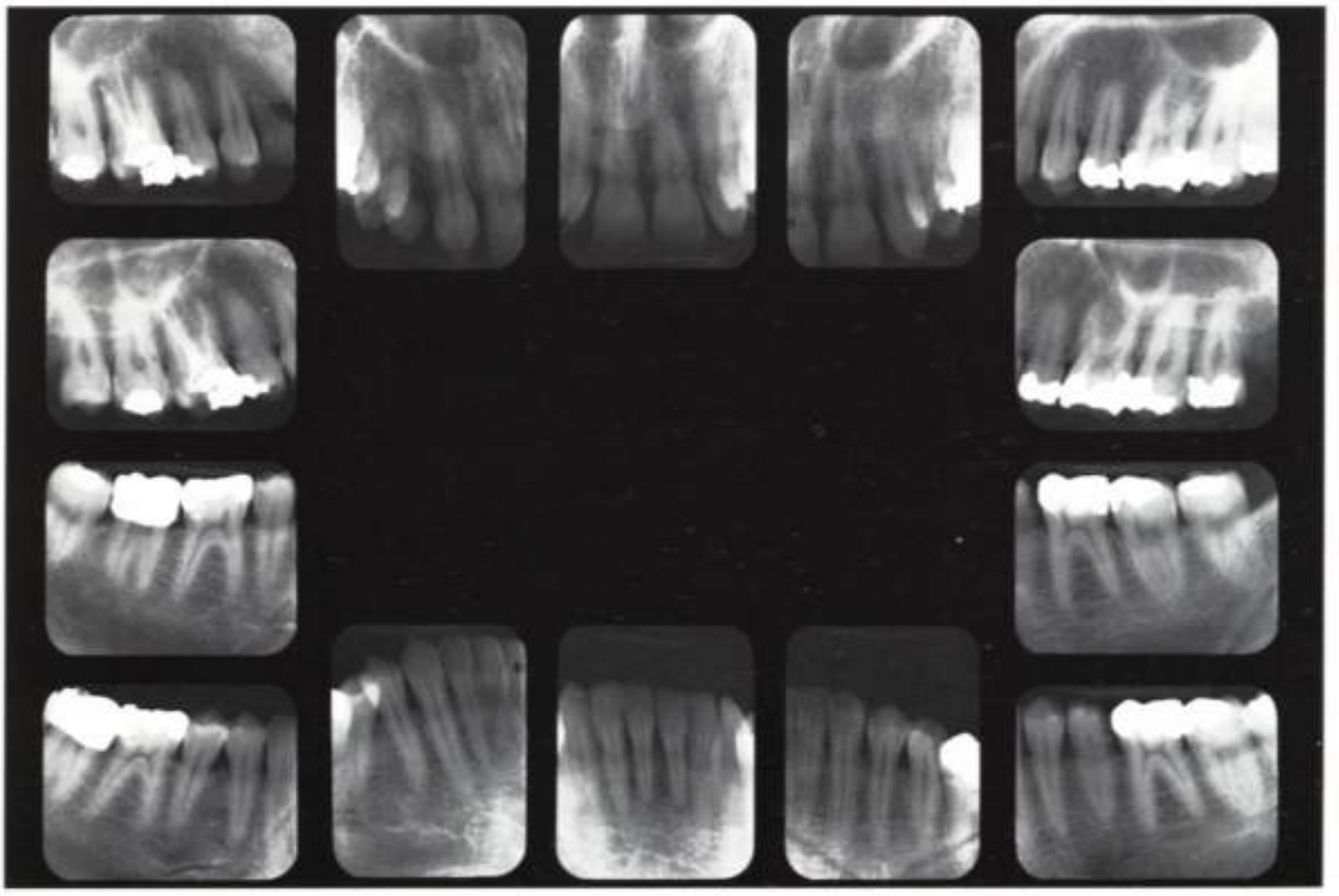
Left: Intraoral periapical film of the upper incisors, clearly showing the abnormal root patterns.

In panoramic views the imaging of upper and lower incisors is often distorted. If necessary, it must be checked with other radiographic techniques.



425 Enlarged panoramic view
Maxillary view of an 8-year-old boy with a cleft lip, jaw, and palate on the left side. The radiograph reveals a supplemental lateral incisor in the cleft region.

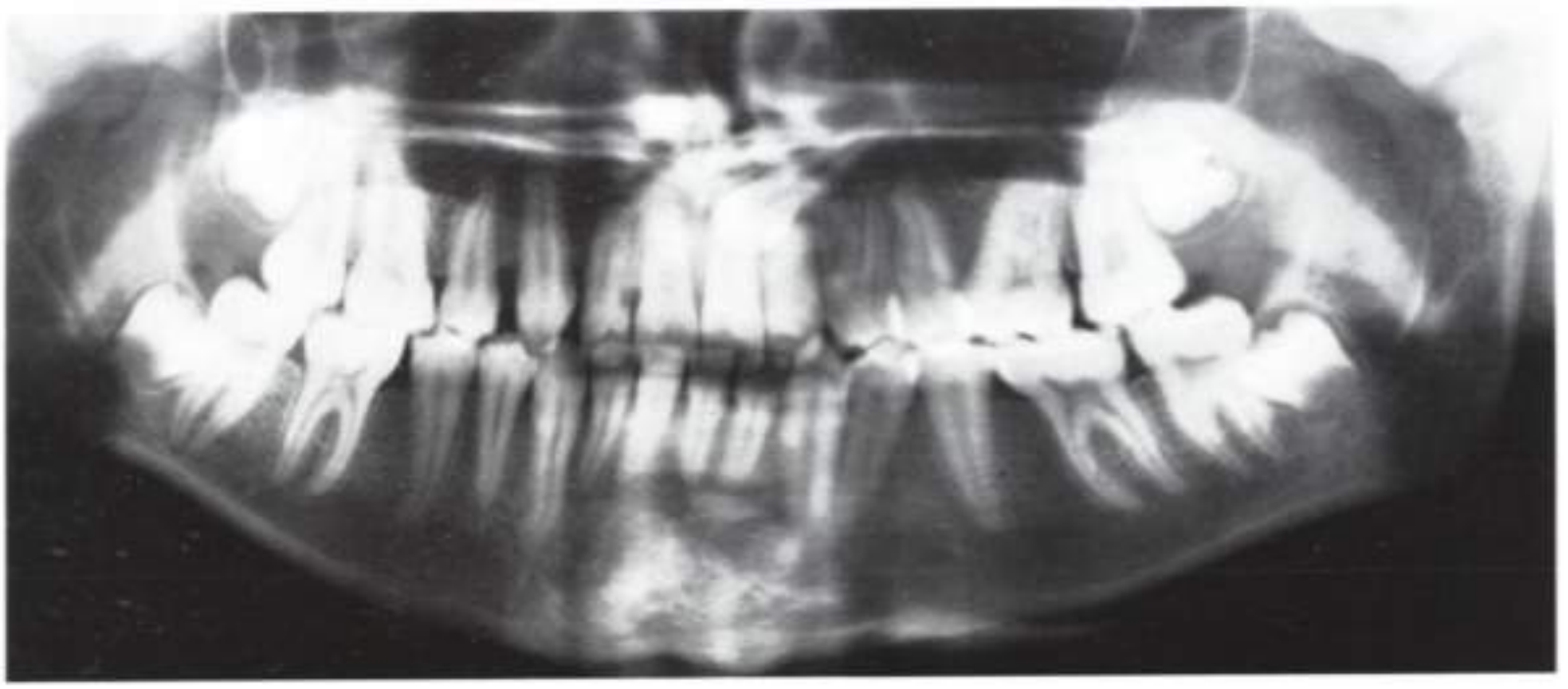
In comparison to the standard panoramic view, this type of intraoral source radiography gives a more precise appearance of the anterior tooth region, but a less precise appearance of the posterior region.



426 Dental condition
The intraoral dental status of a 23-year-old female patient before commencement of orthodontic treatment.

For adults, this should be the technique of choice, as it allows a more accurate assessment of the periodontal condition and of the apices of the roots at the onset. A film holder should be used to ensure tooth-film parallelism.

Radiographic examination for localization of an impacted canine
– Case example –



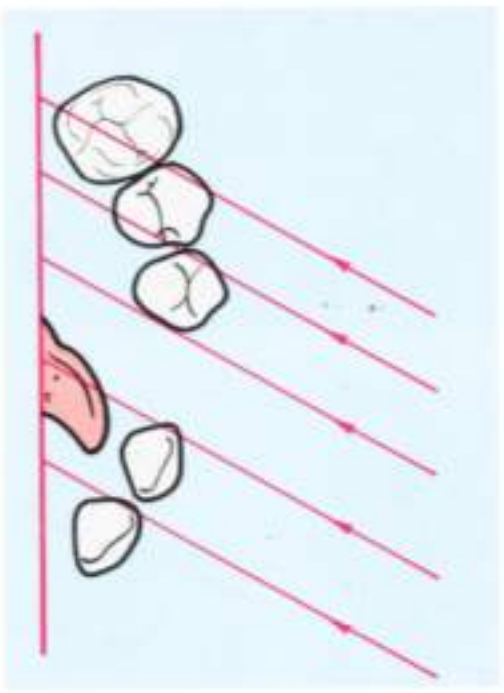
427 Panoramic view
Ectopic and impacted upper left canine in a 16-year-old male. The crown is angled mesially and the root distally.

The position of the impacted tooth cannot be accurately determined from the standard panoramic view.

428 Mesioeccentric periapical view
To determine the position of the canine, an exposure is made with the X-ray tube angled at 30° mesially to the perpendicular projection.

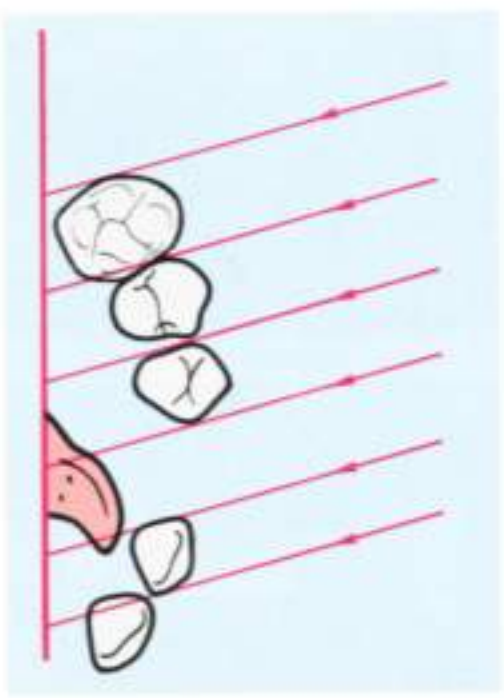
Left: Schematic illustration of the radiographic technique and appearance of the tooth.

Right: Mesioeccentric radiograph of the case in question.



429 Distoeccentric periapical view
A second exposure is made with the tube angled at 30° distally from the perpendicular projection.
Left: Schematic illustration of the exposure direction and appearance of the tooth.
Right: Distoeccentric radiograph of the case in question.

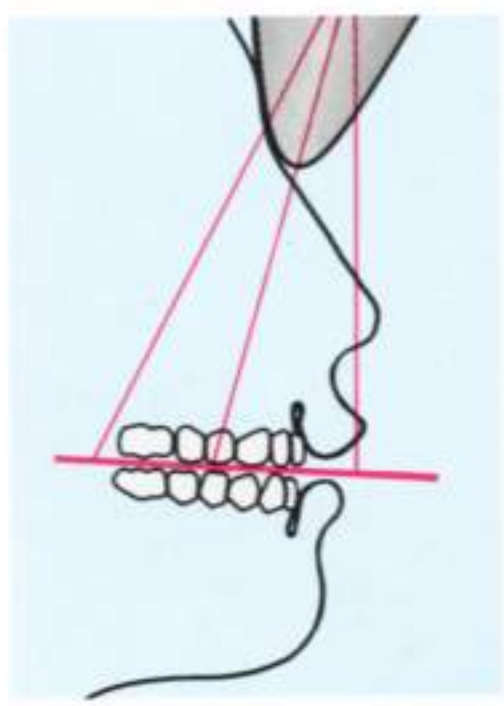
By correlating Figs. 428 and 429, the position can be determined precisely. As the impacted tooth appears to have moved in the same direction as the tube, its location is palatal.

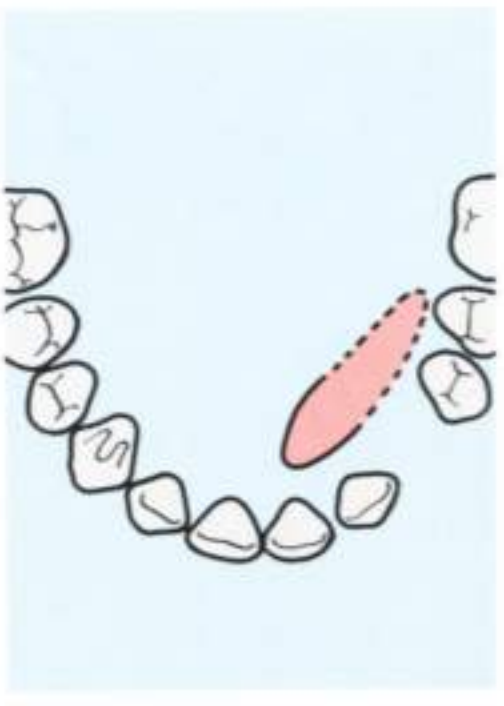


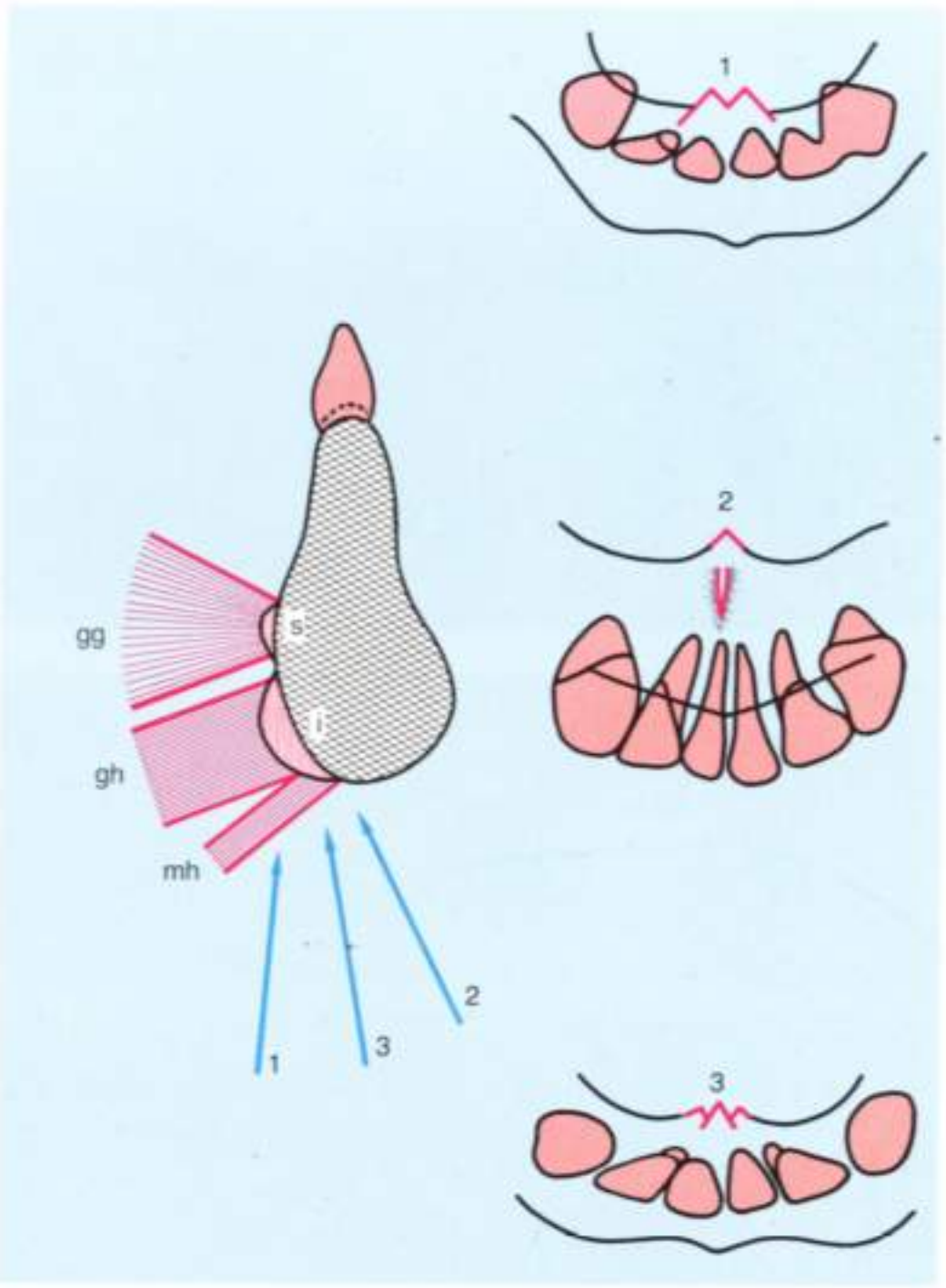
430 Occlusal view
Left: Schematic illustration of the method of exposure.

Center: Radiographic appearance of the palatally impacted upper left canine in the occlusal view.

Right: Schematic drawing of the projection of the tooth in the radiograph.







431 Mental spine (genial tubercle) view

Left: Posterior view of the mental spine (genial tubercles) on the macerated mandible.

Center: Anatomic relations of the mental spine region:

s = mental spine, superior part (superior genial tubercle)
i = mental spine, inferior part (inferior genial tubercle)
gg = genioglossus muscle (paramedian location)
mh = mylohyoid muscle

Arrows 1, 2, 3 indicate the individual exposure directions for the various mental spine projections depicted on the right.

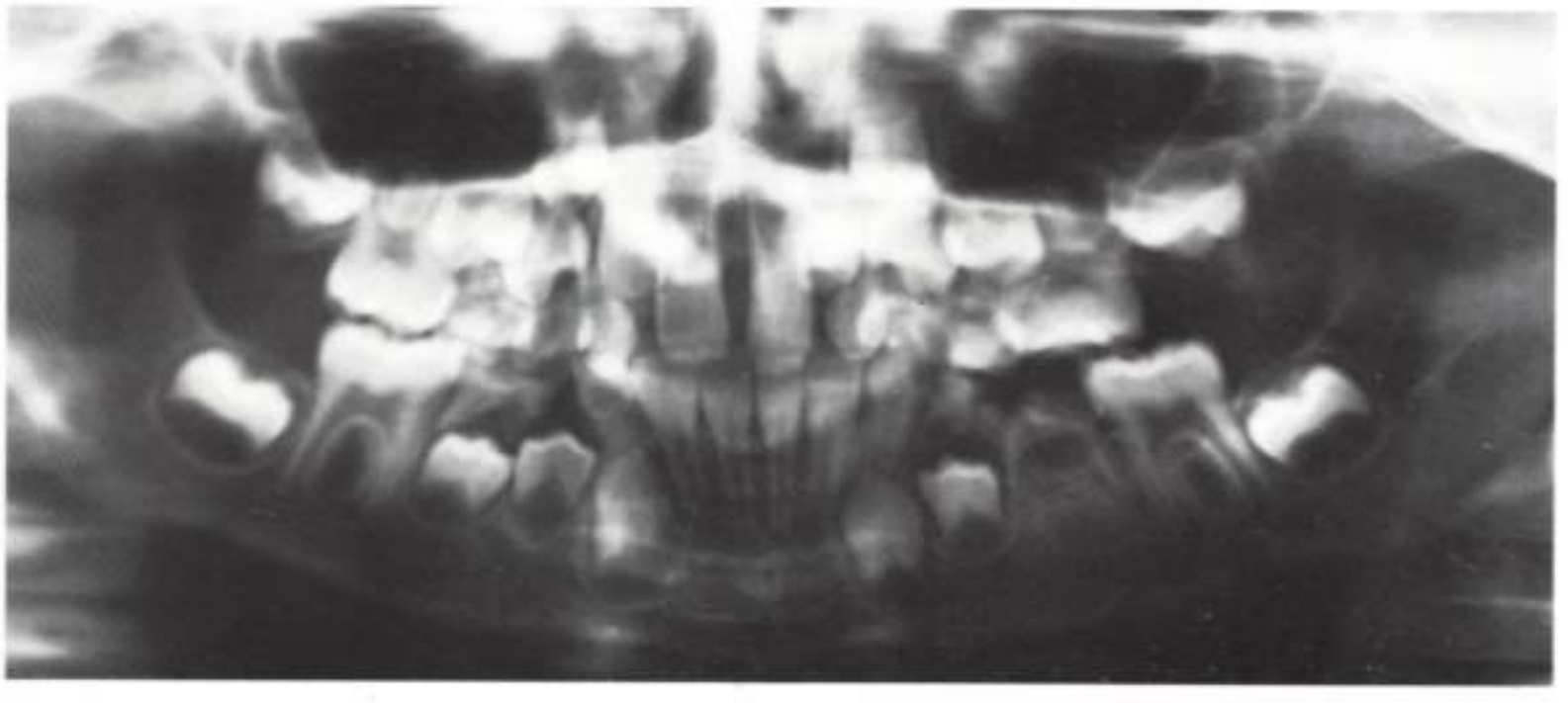
Right: Exposure in the direction of arrow 1 visualizes the double spine of the superior part of the mental spine (superior genial tubercle). Exposure in the direction of arrow 2 shows the unpaired spine of the inferior part (inferior genial tubercle) as well as the bilateral structure of the superior genial tubercle in the center. Exposure in the direction of arrow 3 projects 3 bony spines: the bony contours of the inferior genial tubercle and those of the superior genial tubercles (according to *Schwarz*, 1961).

432 Appearance of the mental spine (genial tubercle) in the radiograph

Left: Superior part of the mental spine (superior genial tubercle) and the mental symphysis zone. Exposure from the direction of arrow 1 in Fig. 431, with the head tilted backward.

Right: Appearance of the median inferior part of the mental spine (inferior genial tubercle) with oblique projection from the direction of arrow 2 (Fig. 431).

In both techniques the film is placed interocclusally.



433 Appearance of the mental spine (genial tubercle) in the panoramic radiograph

8-year-old patient with skeletal mandibular midline shift to the left.

The mental spine (genial tubercle) is often clearly visible in the panoramic view and allows certain deductions concerning the transverse jaw relationships.

Radiologic examinations of dental status during the course of orthodontic treatment

434 Initial examination
The dental condition of a 10-year-old girl before the beginning of orthodontic treatment.

435 Intermediate findings
Panoramic radiograph taken at the end of the active treatment phase. Supernumerary tooth germs can be detected in both lower first premolar regions.

436 Final findings
Postoperative examination after removal of the supernumerary tooth germs and lower third molars. There is an extensive lesion associated with the mesial root of the lower right first premolar. (The upper third molars are yet to be removed.)

The radiologic examinations undertaken in the course of this treatment demonstrate that a single radiologic examination during orthodontic treatment is inadequate.

Photographic Analysis

For the analysis of the relationship between the craniofacial skeleton and the soft-tissue facial contours, *profile* and *frontal* photographs are taken under standardized conditions (Fig. 437).

This is done with the patient sitting upright in habitual occlusion and with relaxed lips and mentalis muscles.

A precondition for obtaining comparable photographs, which can be evaluated by measurement, is a reproducable position of the patient. Such profile and frontal photographic views can be achieved in various ways: (1) the frontal and lateral views are taken with a single camera as described by Simon, with the patient in two different positions; (2) the two photographs are taken with a single camera, obtaining the different aspects by the use of mirrors (A. M. Schwarz); (3) the frontal and lateral views are taken simultaneously, using two cameras (Dausch-Neumann, 1987).

437 Extraoral photographs
In orthodontics, lateral *(left)* and frontal views *(center)* are taken as a rule.

An oblique facial view to assess the smile line can be taken in addition *(right)*.

Profile View

For the profile exposure the camera is placed parallel to the facial midsagittal plane. The patient's head is oriented in accordance with the Frankfurt horizontal plane. The patient's eyes should be looking straight ahead, unstrained, and the ears should be uncovered.

A. M. Schwarz (1958) compiled a detailed classification of the variations of the facial profile (Figs. 441–443).

The evaluation is based upon the construction of three *reference planes:*

1) Eye-ear plane (Frankfurt horizontal plane);
2) Skin nasion perpendicular, according to Dreyfuss;
3) Orbital perpendicular, according to Simon.

The perpendiculars delimit the "jaw-profile field" (JPF). In children this is 13–14 mm wide, in adults 15–17 mm (Fig. 438).

In an *ideal average-value face* the subnasal point touches the skin nasion perpendicular. The "soft-tissue chin point" (the most ventral point of the soft-tissue part of the chin) lies in the center of the "jaw-profile field," the "skin gnathion" (the most inferior chin point) lies on the orbital perpendicular.

Depending on the location of the subnasal point relative to the skin nasion perpendicular, there are typical profile variations: *Average face* = subnasale lying on the skin nasion perpendicular; *anteface* = subnasale lying in front of the skin nasion perpendicular; *retroface* = subnasale lying behind the skin nasion perpendicular.

In straight-jawed ante- and retrofaces the chin is displaced to the same extent as the subnasal point. For each of the above profiles two further facial types can be differentiated, depending on the changed location of the "soft-tissue pogonion" relative to the subnasale. There are *forward-slanting* or *backward-slanting* faces, that means *nine different types of profile* in all.

The *mouth profile* is of great importance for facial expression. The contours of the lower face are, therefore further analyzed by means of the mouth tangent.

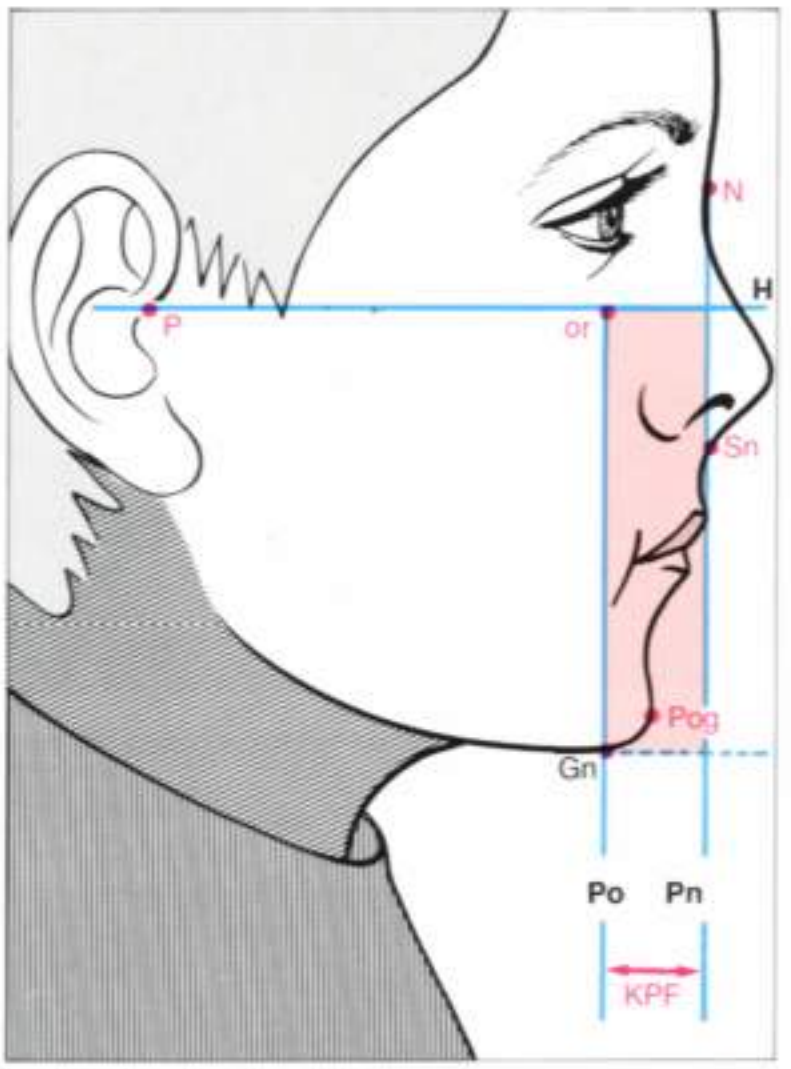
This method of profile analysis has the disadvantage of being affected by a high or low-positioned cartilagenous tragus, and its clinical significance is thereby reduced. The analysis can also be performed on the lateral cephalogram which is preferable as it allows to use the bony landmarks of the external auditory meatus. The clinical value of the photographic picture is that it is more realistic and gives a better record of any changes in the soft-tissue profile during the course of treatment, which is of great advantage.

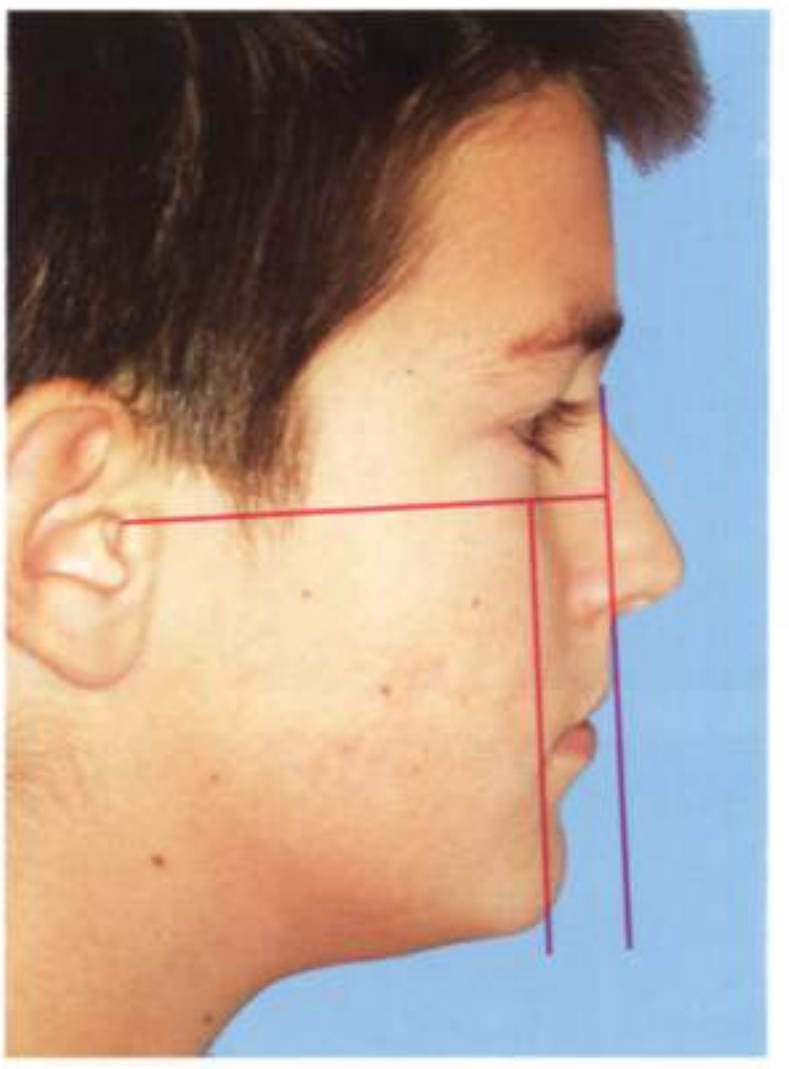
Photographic analysis according to A. M. Schwarz

438 Straight average face

Left: Schematic illustration:
N = Skin nasion
Sn = Subnasale
Gn = Skin gnathion
Pog = Skin pogonion
P = Porion (uppermost point of tragus)
Or = Orbitale (a point, located below the pupil, at a distance equivalent to the gap between the eyelids, with the eyes relaxed and looking straight ahead)
H = Frankfurt horizontal plane
Po = Orbital perpendicular
Pn = Skin nasion perpendicular
JPF = Jaw profile field

Right: Straight average face. The subnasal point lies on the Pn-perpendicular; the vertex of the soft-tissue chin lies at the transition to the posterior third of the JPF.



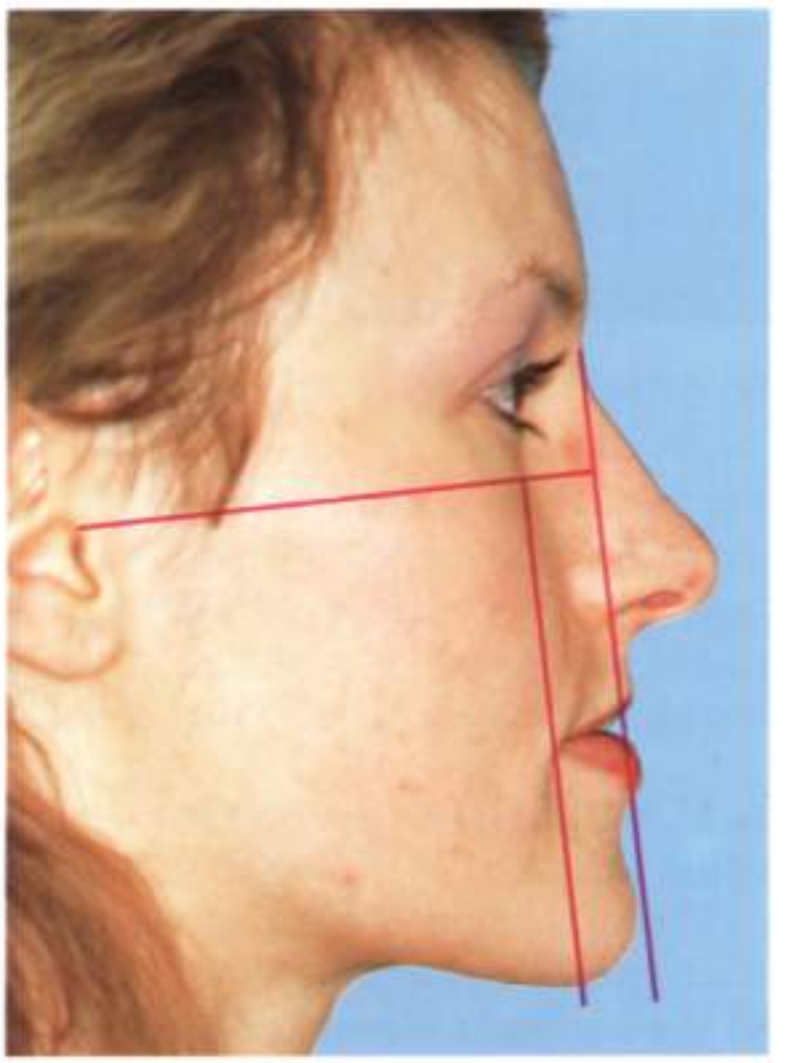


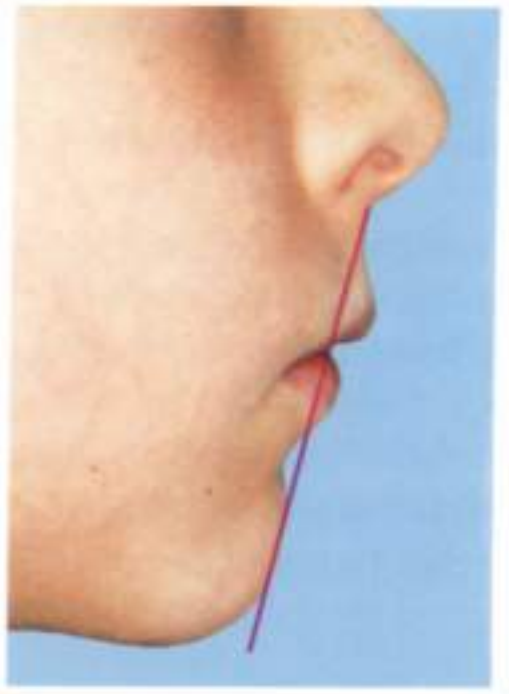
439 Slanting profile

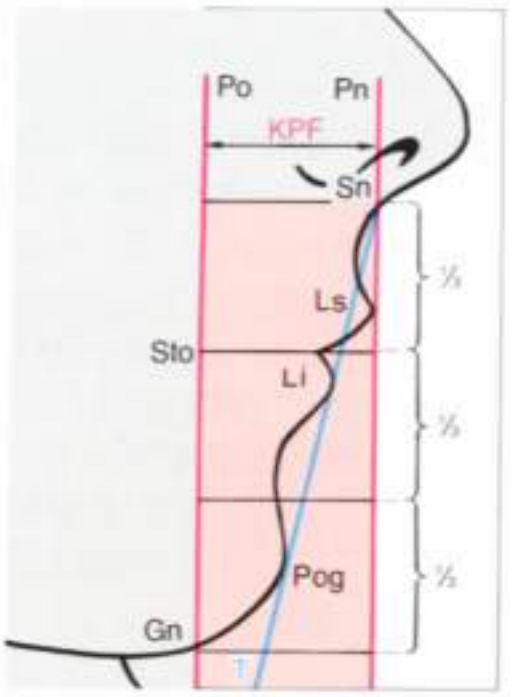
In a slanting profile there is a discrepancy between the subnasal point and the soft-tissue pogonion in relation to the anteroposterior position. This disturbs the harmonious appearance of the facial profile.

Left: Backward-slanting retroface. The subnasal point lies behind the Pn-perpendicular; the soft-tissue chin is displaced more posteriorly than the subnasale.

Right: Forward-slanting anteface. The subnasal point lies in front of the Pn-perpendicular; the soft-tissue pogonion lies disproportionally more anteriorly.







440 Lip profile analysis
Center: Method of evaluation.
Ls = Labrale superius
Li = Labrale inferius
Sto = Stomion
T = Mouth tangent (joins subnasale and soft-tissue pogonion)
In a straight average face the mouth tangent bisects the vermilion portion of the upper lip; it touches the border of the lower lip, and it forms a 10° angle with the Pn-perpendicular.

Left: Protrusive upper and lower lips.
Right: Retrusive lip profile.

The nine possible profile variants according to the classification by A. M. Schwarz

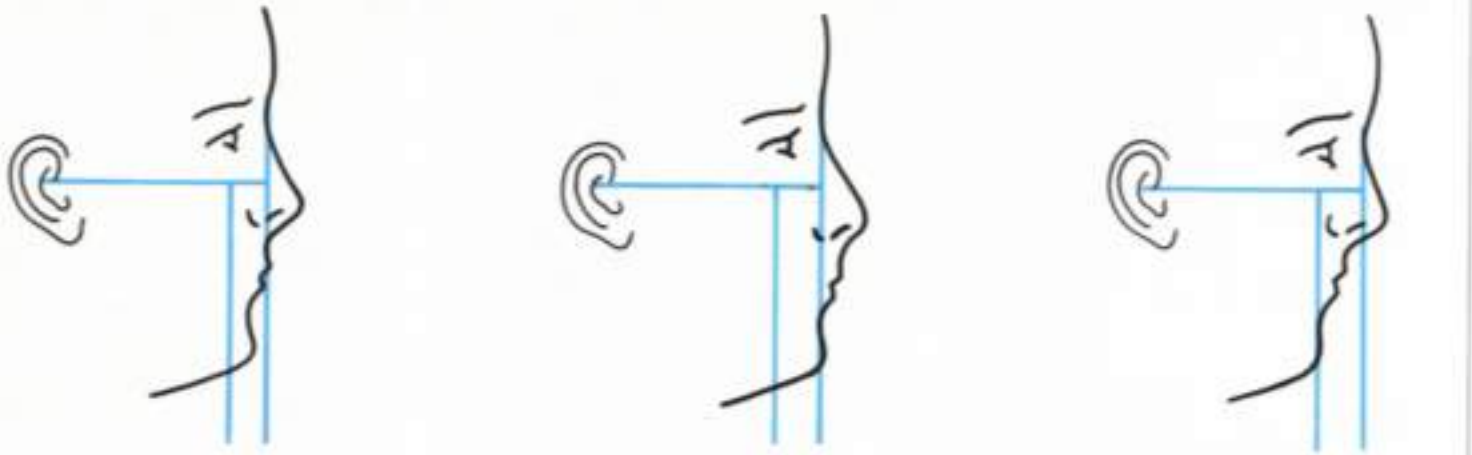
441 Straight-jawed profile
Left: Average face

Center: Anteface

Right: Retroface

A straight-jawed profile – whether an average face, an anteface or a retroface – always looks harmonious. The straight average face (or biometric face) is considered ideal.

Straight profile



Average face | Anteface | Retroface

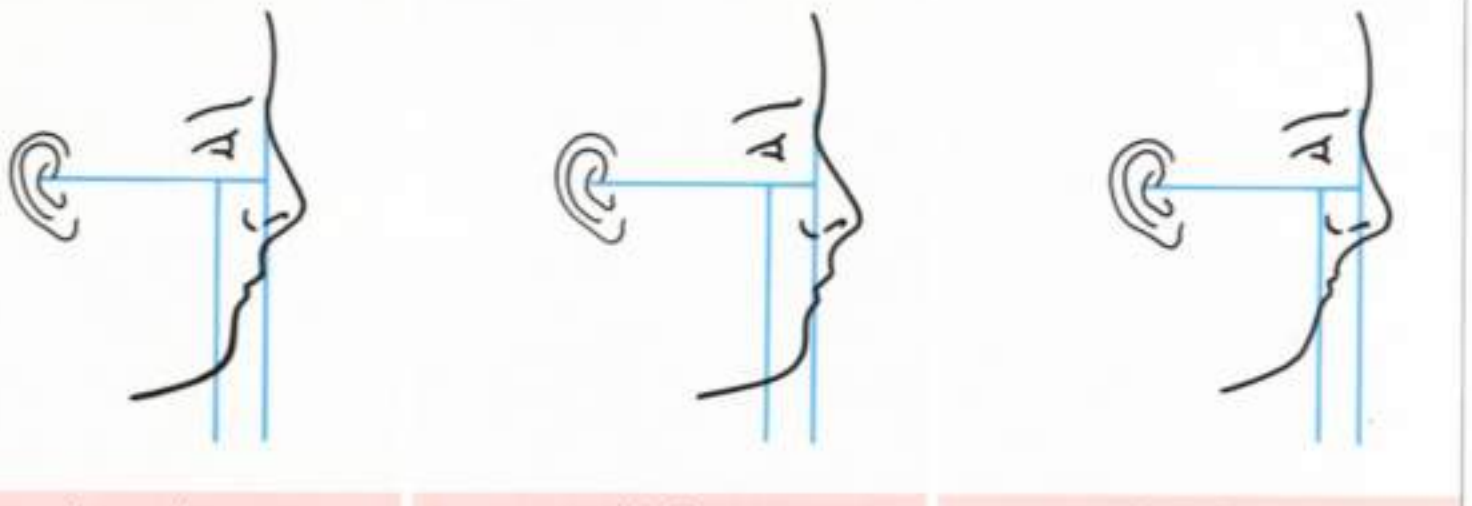
442 Backward-slanting profile
The soft-tissue pogonion is displaced too far posteriorly relative to the subnasal point.

Left: Backward-slanting average face.

Center: Backward-slanting anteface.

Right: Backward-slanting retroface.

Backward-slanting profile



Average face | Anteface | Retroface

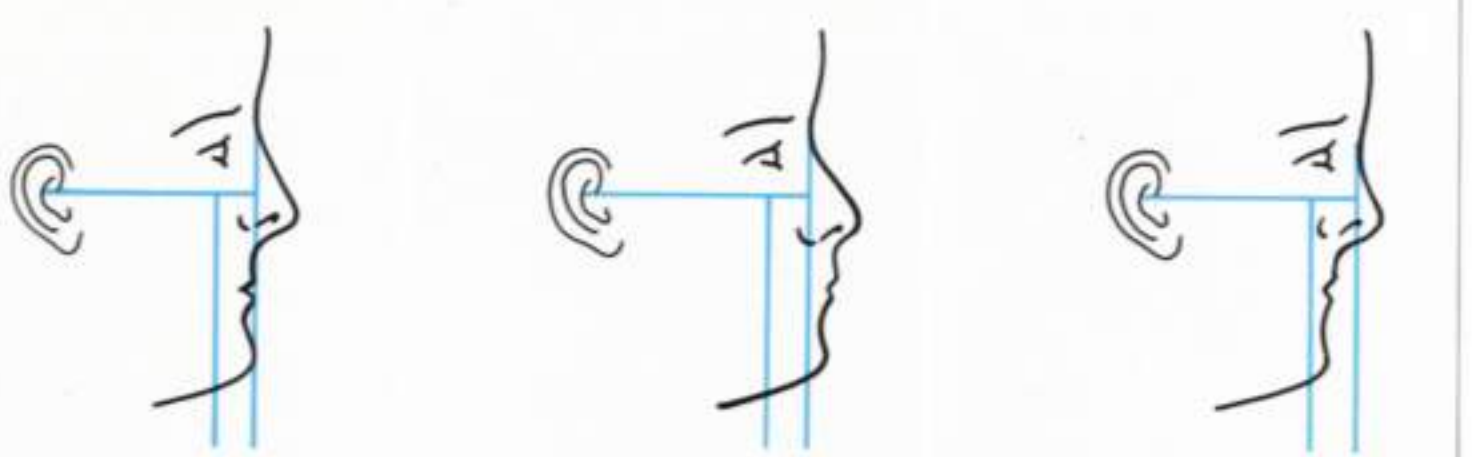
443 Forward-slanting profile
The soft tissue of the chin is too far anterior in relation to the subnasal point.

Left: Forward-slanting average face.

Center: Forward-slanting anteface.

Right: Forward-slanting retroface.

Forward-slanting profile



Average face | Anteface | Retroface

Facial Divergence

Another analysis of the lateral photograph is based upon evaluation of the *divergence of the face*. The inclination between the following two reference lines is here analyzed: (1) The line joining the forehead and the border of the upper lip; (2) the line joining the border of the upper lip and the soft-tissue pogonion.

The following three profile types are differentiated according to the relationship between these two lines:

Straight profile: The two lines form a nearly straight line.

Convex profile: The two reference lines form an angle indicating a relative backward displacement of the chin (posterior divergent).

Concave profile: The two reference lines form an angle indicating a relative forward displacement of the chin (anterior divergent).

Convexity and concavity of the soft-tissue profile

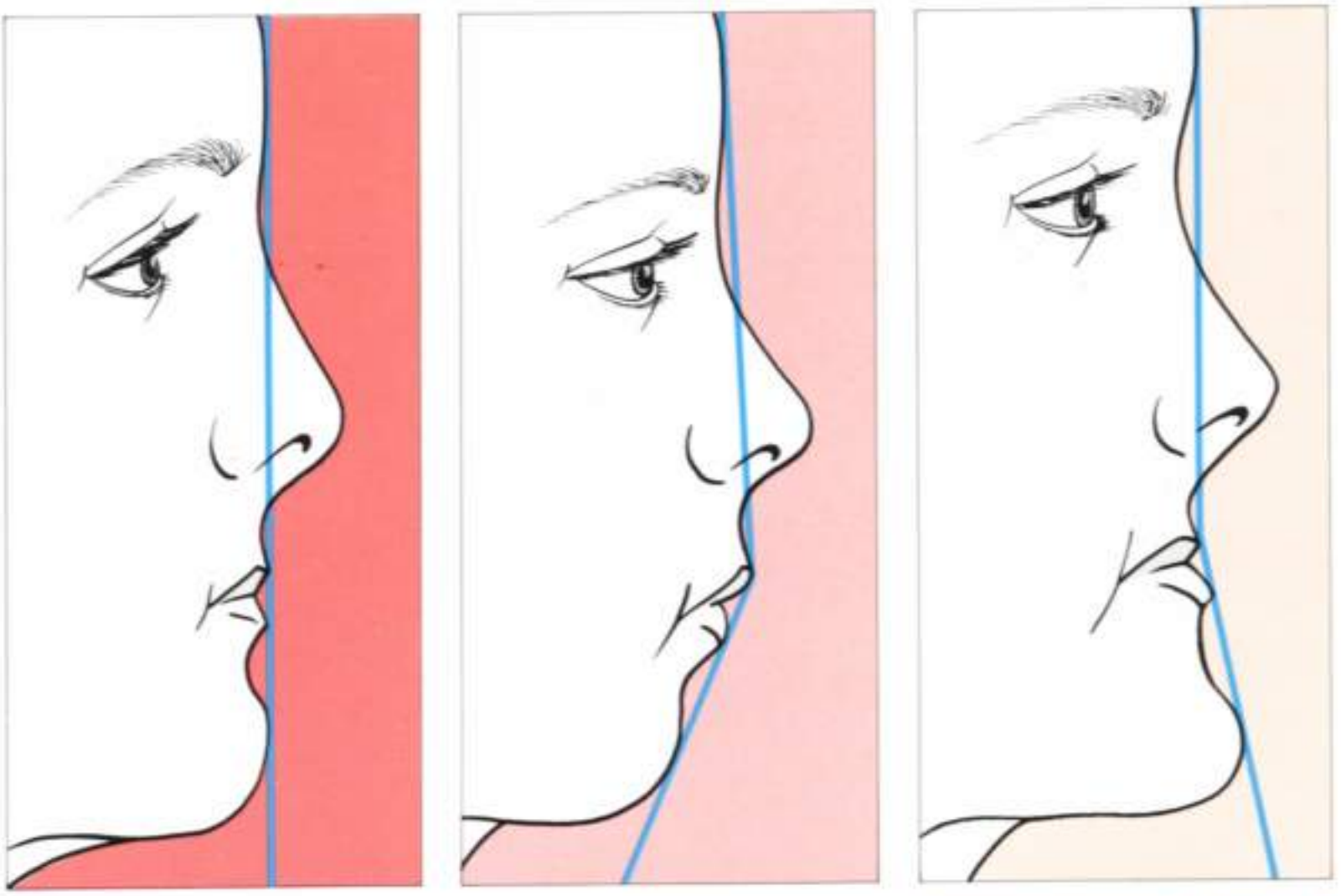
444 Evaluation method
Marking of the reference lines:
Upper line = Joins glabella and border of upper lip.
Lower line = Joins border of upper lip and the vertex of the soft-tissue chin.

Angle formed by the two lines = Facial divergence. Continuous straight line formed = Harmonious profile.

Left: Schematic representation of a straight profile.

Center: A convex profile.

Right: A concave profile.



445 Clinical profiles
Left: Straight profile.

Center: Convex profile.

Right: Concave profile.

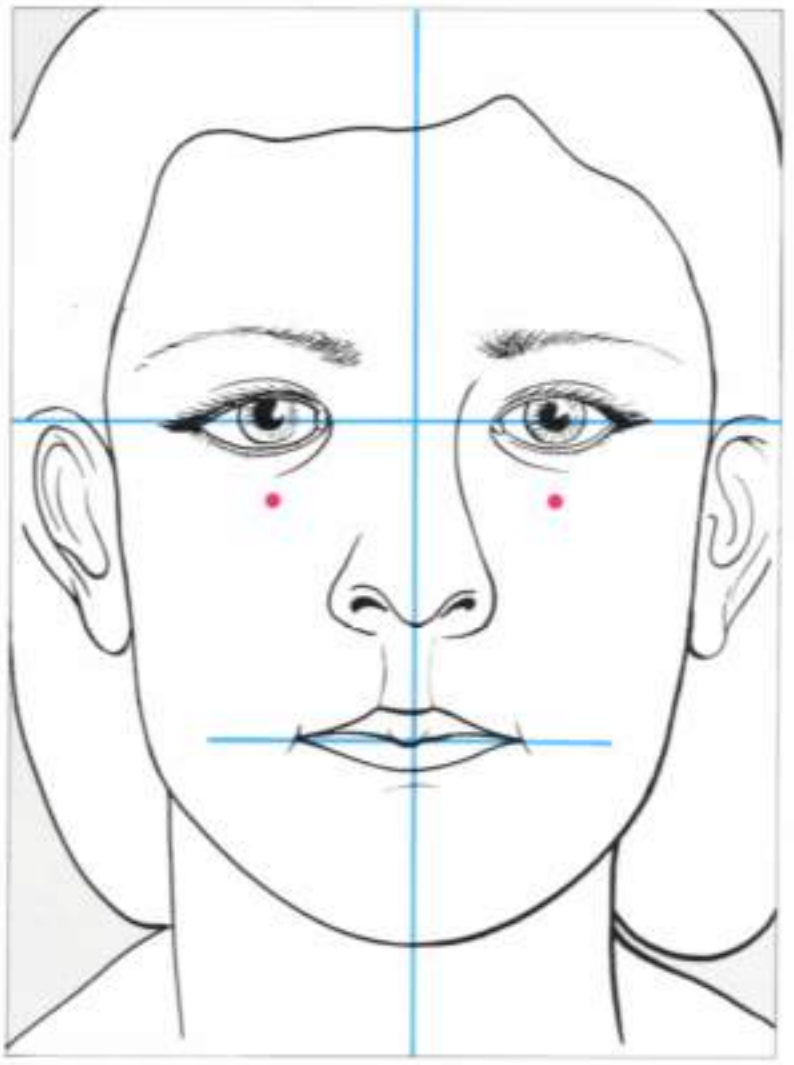
A convex soft-tissue profile suggests a Class II jaw relationship. A concave profile suggests a Class III relation.

The soft-tissue profile influences the physiognomy, but it does not always project the anteroposterior relation of the underlying skeletal structures.

Frontal View

An analysis of the frontal picture is important in assessing major disproportions and *asymmetries* of the face in the transverse and vertical planes. Even a slight rotation of the head from the plane of the film can result in major discrepancies between the relative patterns of the right and left facial contours. It is, therefore, absolutely essential for the camera to be placed perpendicular to the facial midline during the exposure.

For clinical analysis it has proven practical to mark the two orbital points and to construct the skin nasion perpendicular (Fig. 446). During the evaluation of the measurements the diagnostician should bear in mind that a mild degree of physiologic asymmetry between the two sides of the face exists in nearly all normal individuals.

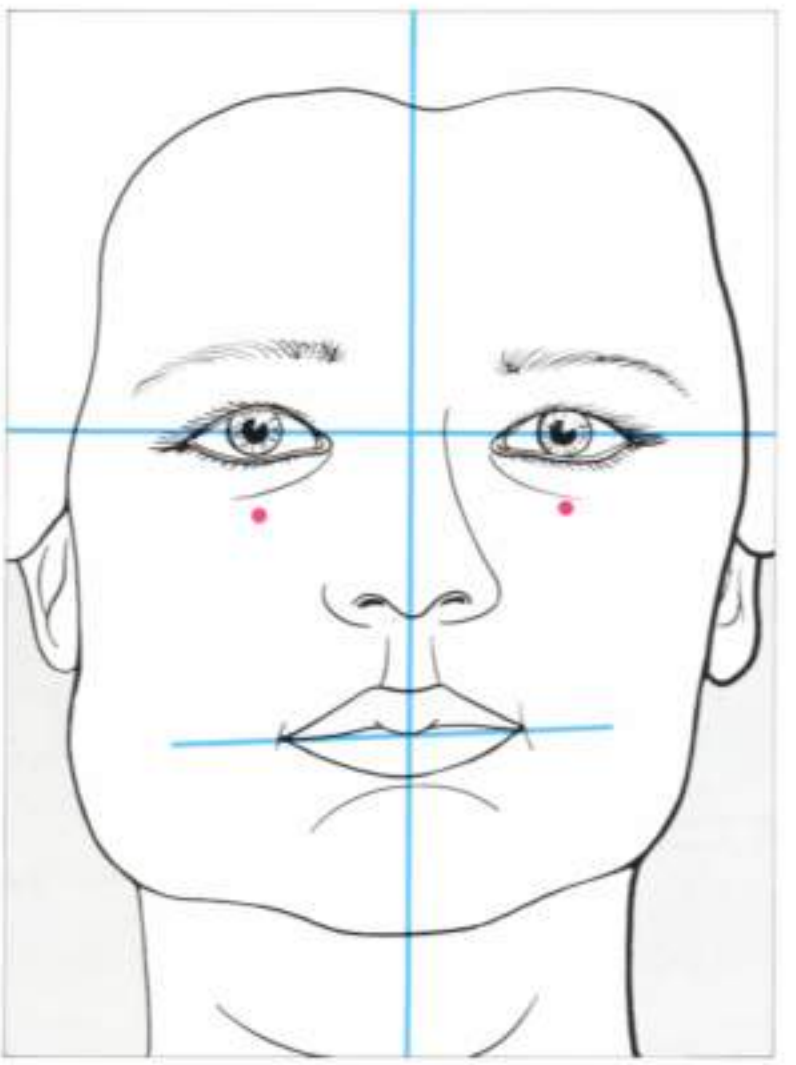


446 Facial symmetry
Right:
Vertical reference plane = Facial midsagittal plane (joins the skin nasion point to the subnasal point);
Upper horizontal plane = Bipupillary plane;
Lower horizontal plane = Parallel to the bipupillary plane through the stomion.

Bilateral marking of the orbital point.

Schematic illustration of a symmetric-proportioned face in the frontal plane.

Left: True frontal picture of the patient.



447 Facial asymmetry
Left: 20-year-old patient with a marked left-right difference in the development of the mandibular body and the mandibular angle.

The relative enlargement of the right side is associated with hyperplasia of the right masseter muscle.

Right: Schematic illustration of the photographic evaluation.

Photographic representation of facial asymmetry

448 True frontal picture
11-year-old boy with a noticeable difference between the right and left sides of the face.

449 First composite frontal picture
Altered facial form after photomontage of the two right sides of the face.

450 Second composite frontal picture
Frontal view after photomontage of the two left facial sides of the patient from Fig. 448.

The photographic method illustrates the difference in the configuration of the two sides of the face. A certain asymmetry in the facial pattern is physiologic, however.

Cephalometric Analysis of the Lateral Radiograph

Although the cephalometric radiograph in standard lateral projection was introduced into orthodontics during the 1930s, the method has only become routine in recent years. Today, cephalometric analysis has firmly taken its place in dentofacial diagnostic procedures. In principle, the analysis is only *one* of various diagnostic records made when planning treatment. "Cephalometric diagnosis," i.e. diagnosis and treatment planning exclusively from the radiograph, is wrong and inadequate. The *cephalometric radiograph* registers the anteroposterior and vertical configuration of the facial skeleton, but provides no information about other important criteria, for example, the transverse dimension or functional relations.

An infinite number of reference points, lines, and measurements can be made on the lateral headfilm. However, the only useful radiographic cephalometric measurements are those which are of relevance to the treatment planning. The *following information* can be ascertained from the cephalometric analysis:

- **Configuration of the facial skeleton**
- **Relationship of the jaw bases**
- **Relationship of the axial inclination of incisors**
- **Assessment of the soft-tissue morphology**
- **Growth pattern and direction**
- **Localization of the malocclusion**
- **Treatment possibilities and limitations**

In cephalometric radiography, the considerable distance from X-ray source to subject (1.5–4 meters) allows exact reproduction of the facial skeleton with minimum enlargement or distortion. For cephalometric analysis it is essential to locate *reference points* in the region of the craniofacial skeleton from which reference lines and planes can be constructed. These can then be measured linearly or angularly.

The most difficult aspect of cephalometrics is the *interpretation of the individual measurements.* In order to assess the individual variations of facial structures, it is necessary to establish their mutual relationships. *Correlative analyses* are the most suitable for diagnostic purposes; the recording of individual values is insufficient. Individual measurements are not relevant for two reasons:

1) The so-called mean values, to which the individual value is compared, are only standard values which provide a crude orientation but do not necessarily define a malocclusion or treatment goal.

2) By summation or compensation of the individual measurements which differ from the mean value, borderline readings can be obtained and extreme readings can be compensated even in case of severe skeletal discrepancies.

Cephalometric Reference Points

Reliable evaluation of a cephalometric radiograph depends on accurate definition and localization of landmarks, since these provide the basis for subsequent measurements and analyses.

Reference points are usually located in the *skeletal, dentoalveolar* and *soft tissue regions.* In contrast to anthropology, radiographic cephalometrics include anatomic, radiographic (intersection of two X-ray shadows), and constructed points (e.g. S = center of the hypophyseal fossa i.e. sella turcica).

Anatomic reference points are located on or within the skeletal structures; (e.g. Nasion, A-point, B-point, ANS, Pogonion, Menton).

In general, unilateral reference points in the midsagittal plane exhibit greater accuracy than bilateral ones (e.g. Gonion).

The *precision of location* of reference points depends on the quality of the radiograph, the density of the structure, in particular, the surrounding and overlapping struc-

451 Radiographic cephalometric reference points – Definitions

N = Nasion; the most anterior point of the frontonasal suture in the midsagittal plane

S = Midpoint of sella; sella point (S) is defined as the center of the sella turcica. It is a constructed (radiologic) point in the median plane

Se = Midpoint of the entrance to the sella

Cond = Condylion; the most posterior superior point of the condyle

ar = Articulare; a constructed point at the intersection of the images of the posterior margin of the ramus and the outer margin of the cranial base

Ba = Basion; lowest point on the anterior margin of the foramen magnum in the median plane

T_1 = Most posterior point on the ramus in the region of the angle of the mandible

Go = Gonion; a constructed point at the intersection of the lines tangent to the posterior border of the ramus and the lower border of the mandible

T_2 = Most posterior inferior point on the body of the mandible

Me = Menton; the most inferior point of the outline of the symphysis in the midsagittal plane

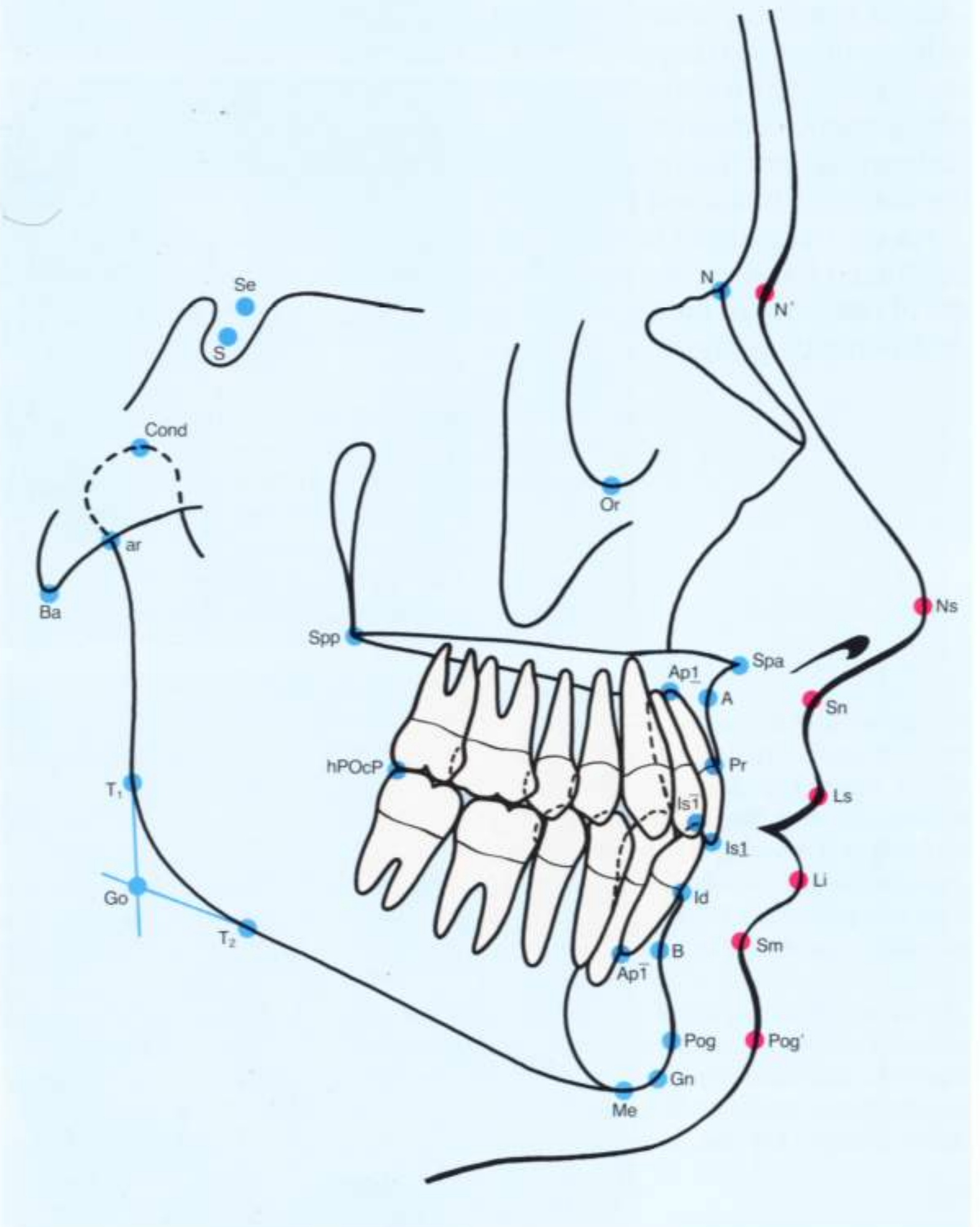
Gn = Gnathion; the most anterior inferior point on the bony chin

Pog = Pogonion; the most anterior point of the bony chin in the midsagittal plane

B = Point B, supramentale; the deepest point on the outer contour of the mandibular alveolar process between infradentale and pogonion

Id = Infradentale; the most anterior superior point on the alveolar process between the mandibular central incisors in the median plane

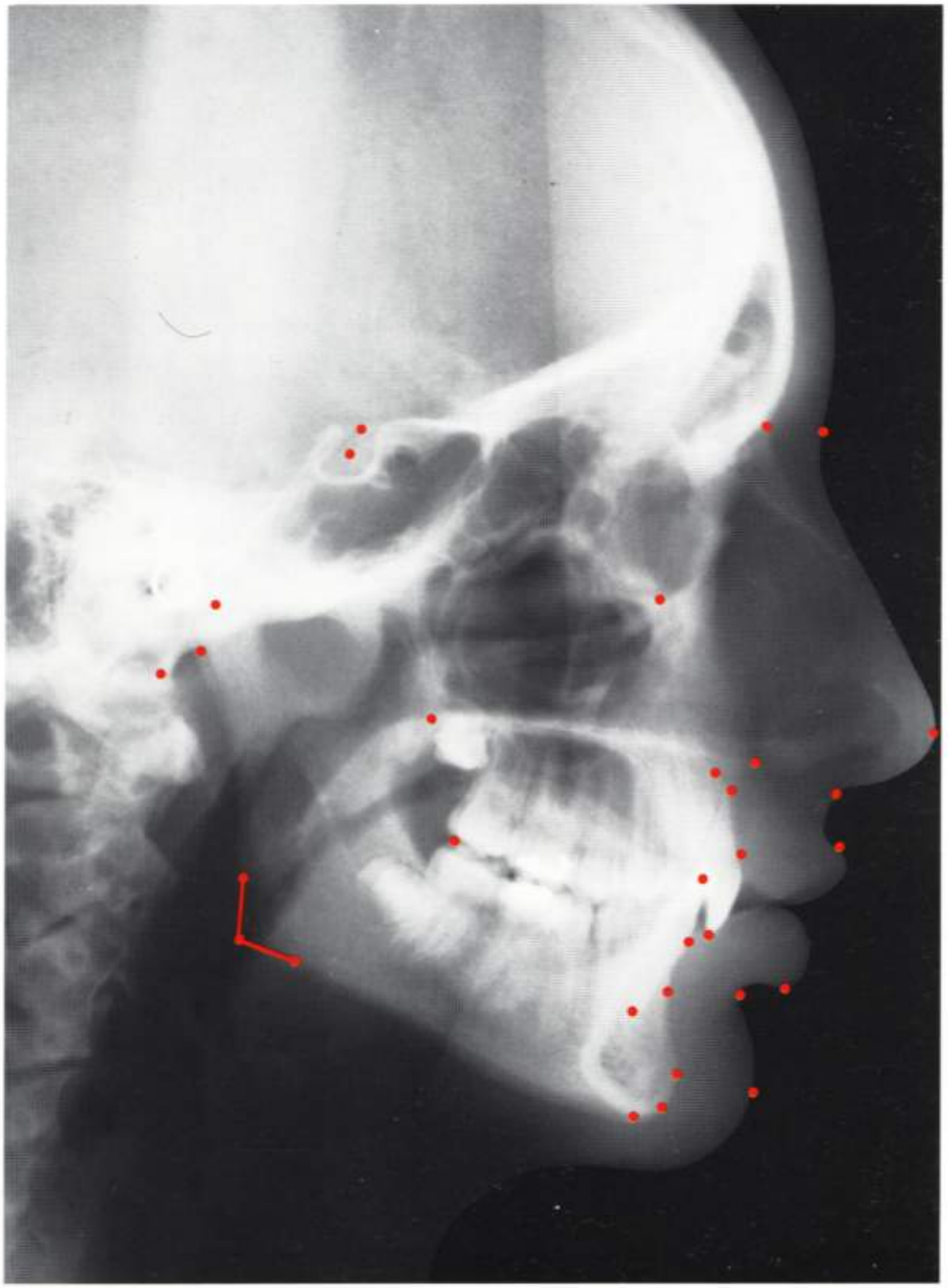
Pr = Prosthion; the most anterior inferior point on the alveolar portion of the premaxilla between the upper central incisors in the median plane



tures and on the experience of the diagnostician. The most difficult points to locate among others include Basion, Orbitale, A-point, anterior nasal spine (ANS), posterior nasal spine (PNS), and the apex point of the lower incisor. As a rule, anatomic and radiographic points are more accurate than constructed points as in the latter the methodological error of individual point localization accumulates.

The *constancy* of the reference points is variable during craniofacial growth. A so-called "fixed landmark" does not exist. Points which are situated close to the base of the skull (e.g. Sella, Nasion, Basion), however, show little variation with growth after infancy.

The reference points described in this chapter are used in the following cephalometric analysis on account of their balance in reliability and validity.



A = Point A, subspinale; the deepest midline point on the anterior outer contour of the maxillary alveolar process between the anterior nasal spine and prosthion

ANS = Anterior nasal spine; the most anterior point of the tip of the anterior nasal spine in the midsagittal plane

PNS = Posterior nasal spine; a constructed radiologic point; the intersection of the continuation of the anterior wall of the pterygomaxillary fissure and the nasal floor.

Or = Orbitale; lower-most point of the bony orbit

Is $\underline{1}$ = Incision superius; incisal tip of the crown of the most anterior maxillary central incisor

Ap $\underline{1}$ = Apex point of the most anterior maxillary central incisor

Is $\overline{1}$ = Incision inferius; incisal tip of the crown of the most anterior mandibular central incisor

Ap $\overline{1}$ = Apex point of the most anterior mandibular central incisor

PPOcP = Posterior point of the occlusal plane; the most distal point of contact between the most posterior molars in occlusion

N' = Skin nasion; located at the point of maximum concavity between the nose and forehead

Ns = Tip of nose; the most anterior point of the soft-tissue nose

Sn = Subnasale; a skin point; the point at which the columella merges with the integument of the upper lip

Ls = Labrale superius; edge of upper lip

Li = Labrale inferius; edge of lower lip

Sm = Inferior labial sulcus i.e. mentolabial fold; point at which the labrale inferius meets soft-tissue pogonion

Pog' = Soft-tissue pogonion; the most anterior point of the soft-tissue chin

Cephalometric Reference Lines

Reference lines or reference "planes" must be constructed before angular, linear, and proportional measurements can be made. The majority of reference lines are defined as a straight line connecting two landmarks (e.g. N-A line = Line joining N to point A) (compare Fig. 451).

The lines most frequently used include (Fig. 452):

Anterior cranial base line = Line joining point S and N or point Se and N

Lateral cranial base line = Line joining point S and ar

Palatal plane = Maxillary plane; line joining ANS to PNS

Occlusal plane = Line joining the midpoint of the anterior overbite and point PPOcP

Mandibular plane = Line joining point Me and T_2

Ramus line = Line joining point ar and T_1

452 Radiographic cephalometric reference lines

1 = Anteroposterior extent of the anterior cranial base (according to *A.M.Schwarz*)

2 = Anterior cranial baseline

3 = Lateral extent of cranial baseline

4 = Palatal plane, maxillary baseline

5 = Occlusal plane

6 = Mandibular plane, mandibular baseline

7 = Ramus length

8 = Y-axis

9 = Facial depth

10 = Pn-line (according to *A.M.Schwarz*)

11 = Constructed "ideal Frankfurt horizontal" (according to *A.M.Schwarz*)

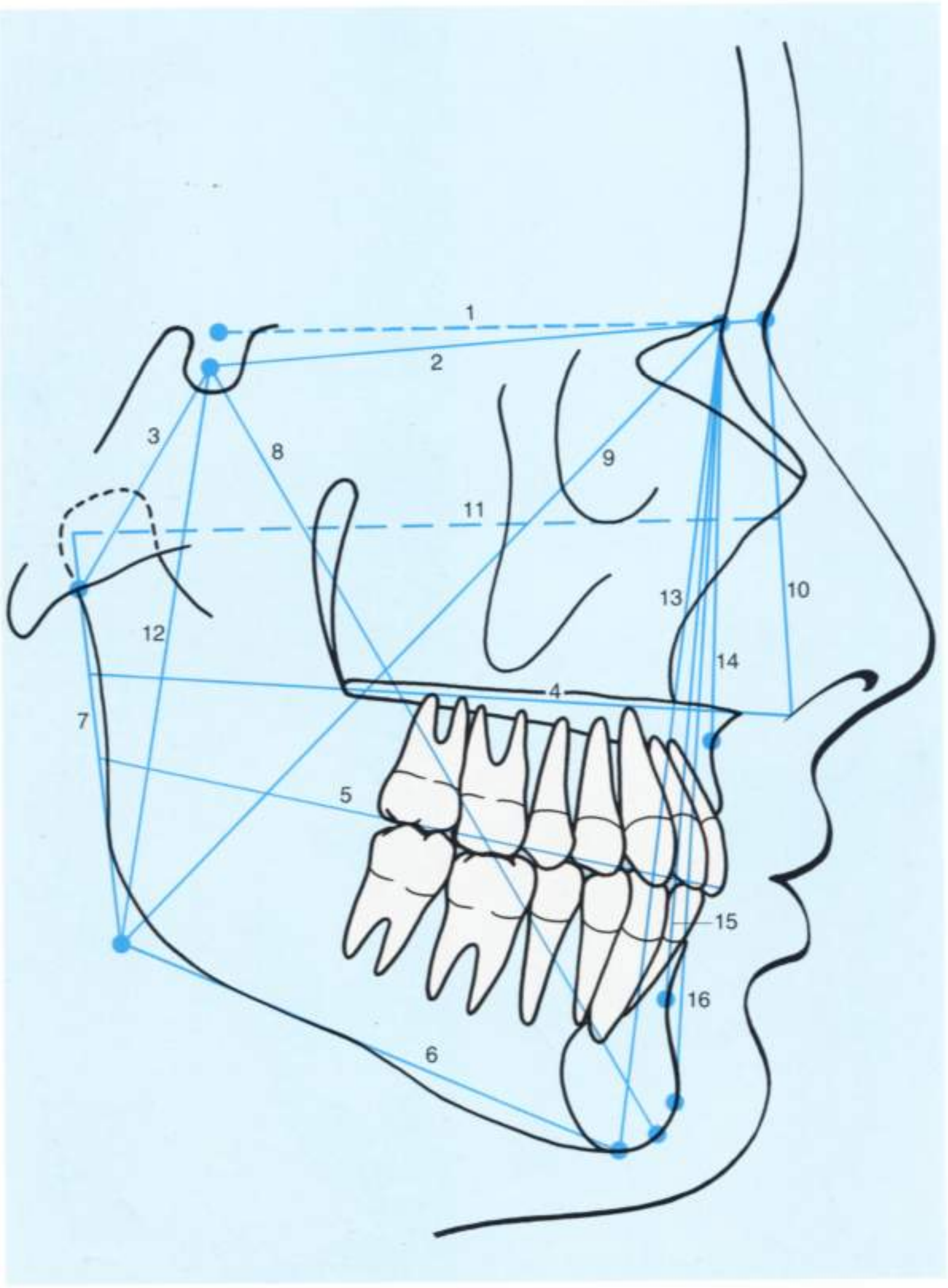
12 = Posterior facial height

13 = Anterior facial height

14 = Line joining nasion and point A

15 = Line joining nasion and point B

16 = Line joining nasion and pogonion



Y-axis = Line joining point S and Gn

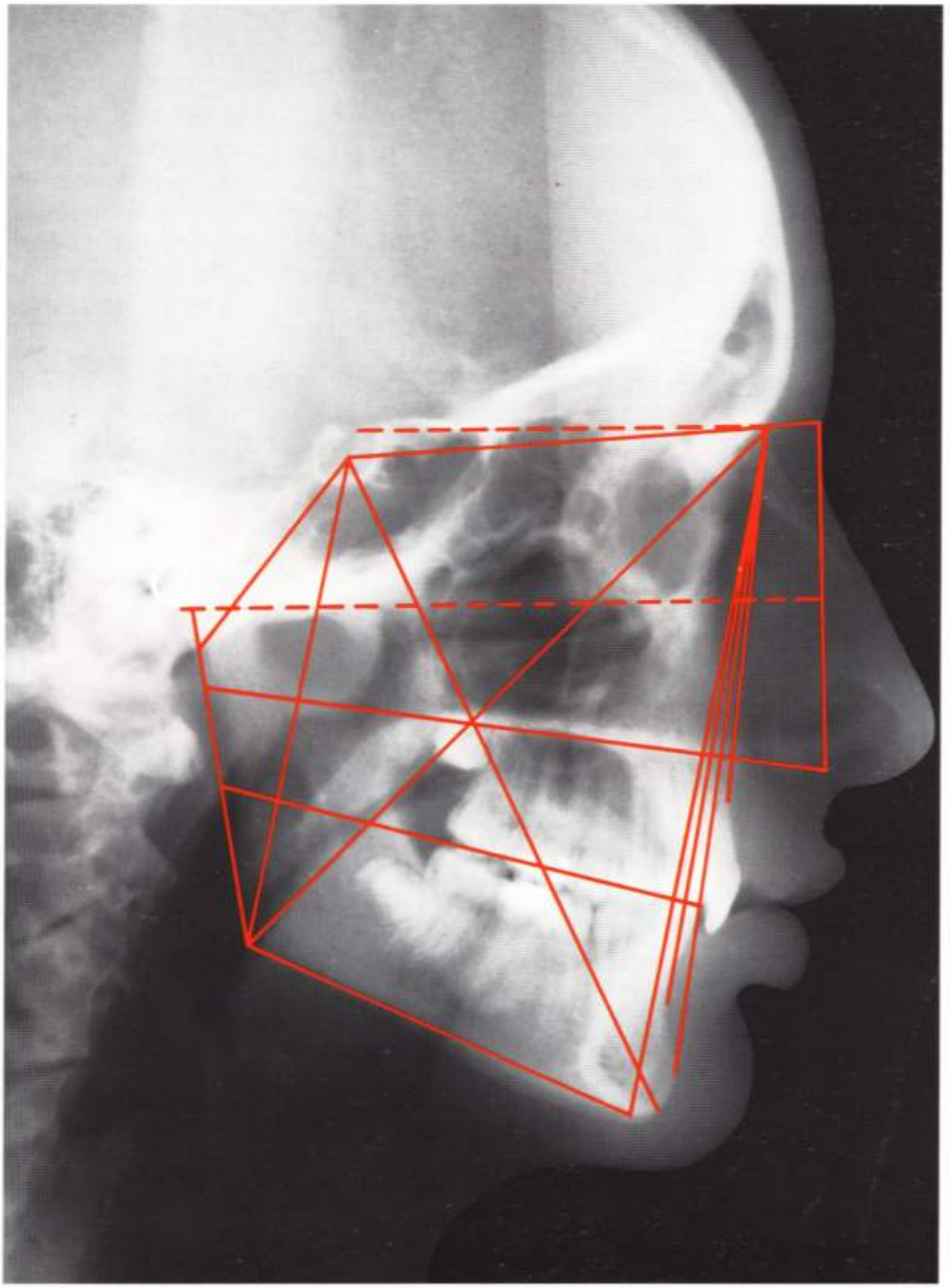
Facial depth = Line joining point N and Go

Pn-line = Perpendicular on the SeN-line at point N' (= Point located 8 mm anterior to point N) extended downward to the palatal plane (according to A. M. Schwarz)

Ideal Frankfurt horizontal = A straight line drawn parallel to SeN from the midpoint of nasal perpendicular (according to A. M. Schwarz)

Posterior facial height = Line joining point S and Go

Anterior facial height = Line joining point N and Me



Reference lines on the lateral cephalogram

Interpretation of Cephalometric Measurements

The aims of interpretation may be summarized as follows:

- Analysis of skeletal structure and facial type
- Assessment of vertical and sagittal relationship between maxillary and mandibular bases
- Differentiation of skeletal and dentoalveolar malocclusions
- Analysis of dental relationships
- Analysis of soft tissues regarding etiology and prognosis

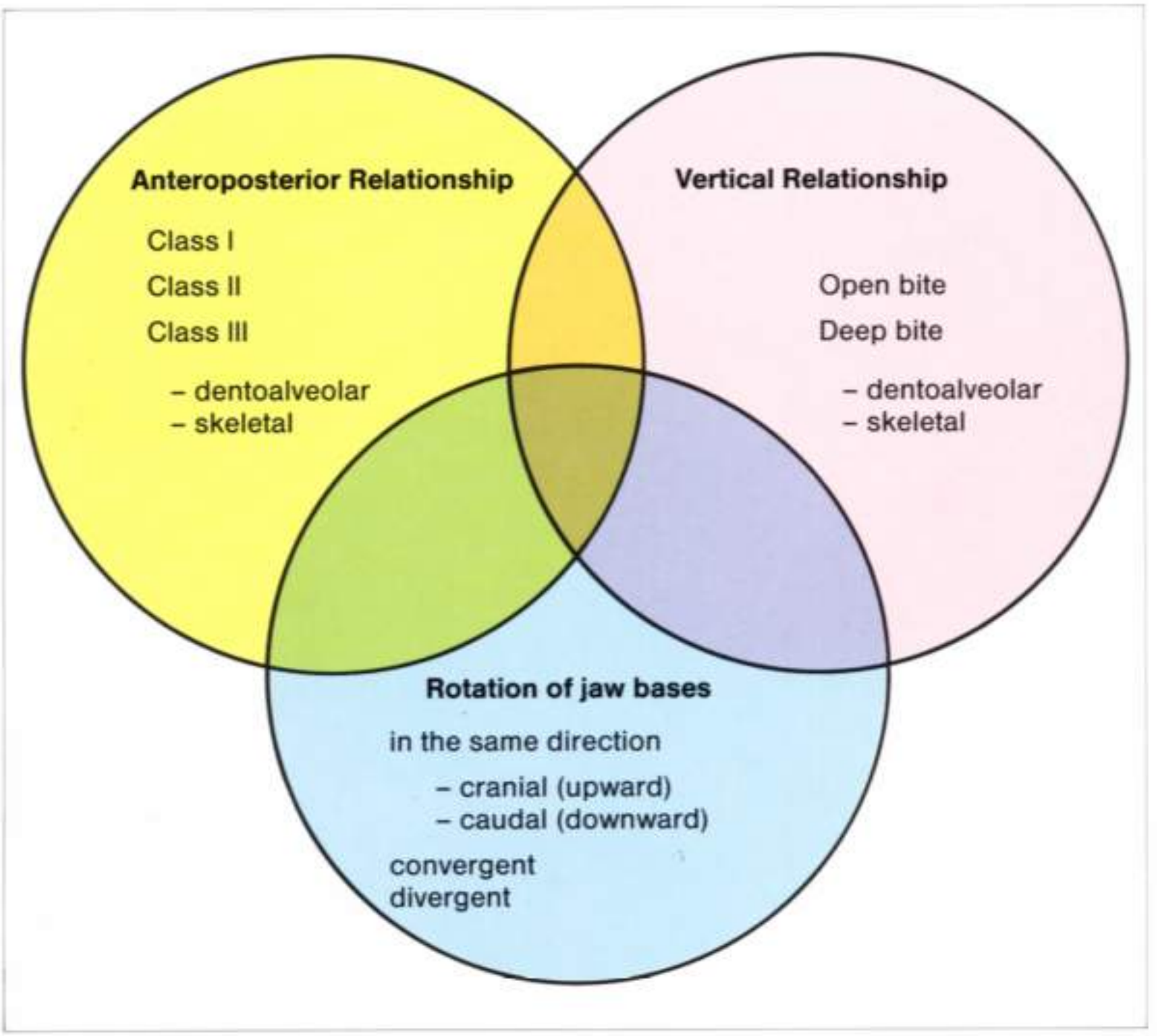
Cephalometric radiography will give an accurate definition of *facial type*. No close correlation exists between facial type and anomaly. Malocclusions as well as ideal occlusions occur in all facial types.

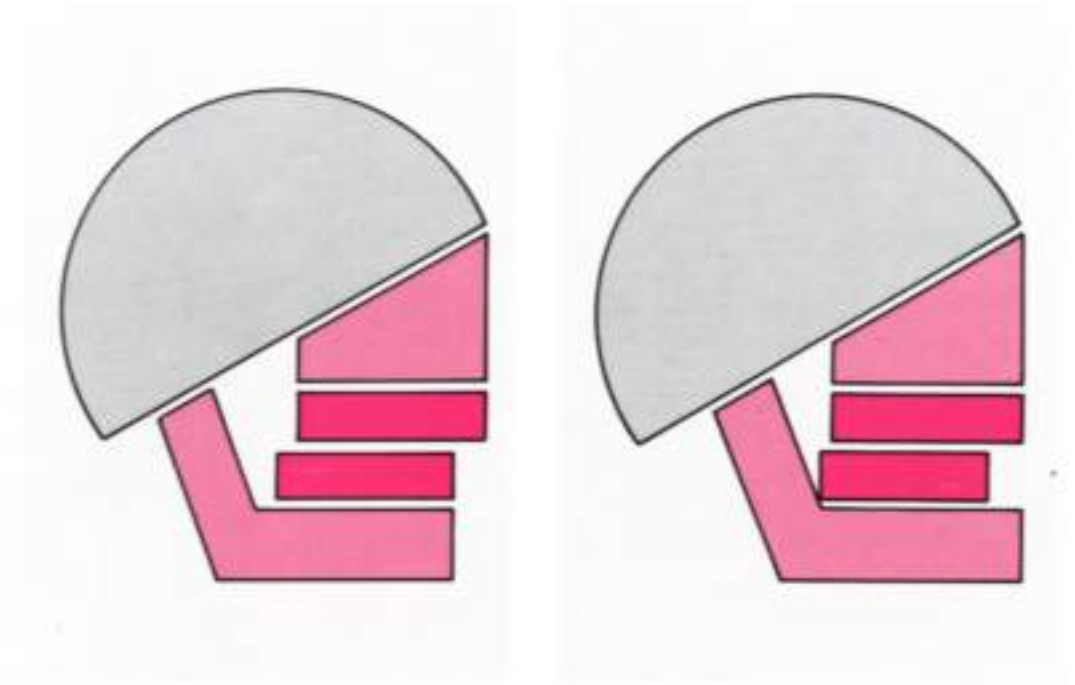
Determination of skeletal relationships is important in treatment planning despite the fact that no definite correlation has been established. Dentoalveolar and skeletal anomalies can be differentiated according to the vertical and sagittal relationships of the jaw bases, i.e. the measurements help determine whether the abnormality is purely the result of tooth malpositions, i.e. localized primarily to the area of the alveolar process or whether a dysgnathia is present as a result of skeletal discrepancies, e.g. in the region of the jaw bases. Successful treatment of a *skeletal malocclusion* is only possible during the growth period or by orthognathic surgery, whereas correction of *dentoalveolar* anomalies can be carried out at a later stage. Late treatment of skeletal abnormalities is only possible by compensatory treatment measures whereby the clinical appearance of a skeletal malocclusion is corrected by moving groups of teeth in the dentoalveolar region. This *compensatory possibility* is limited and in severe cases a combined orthodontic-surgical approach is indicated at the end of the growth period.

Analysis of incisor position and relation to the jaw bases is important from the diagnostic as well as the therapeutic standpoint. The clinical appearance of the dysgnathia can be compensated or aggravated depending on the axial inclination of the incisors. The deciding factor with respect to treatment possibilities is whether the teeth need to be tipped or moved bodily, i.e. whether the change in incisor position requires simple or complex treatment mechanics.

453 Classification of the most important skeletal malocclusions
Correct interpretation of the most significant measurements forms the basis of a relevant cephalometric analysis.

Every abnormality is characterized by deviation of the jaw bases in the sagittal and vertical plane as well as rotation of the jaw bases toward one another.

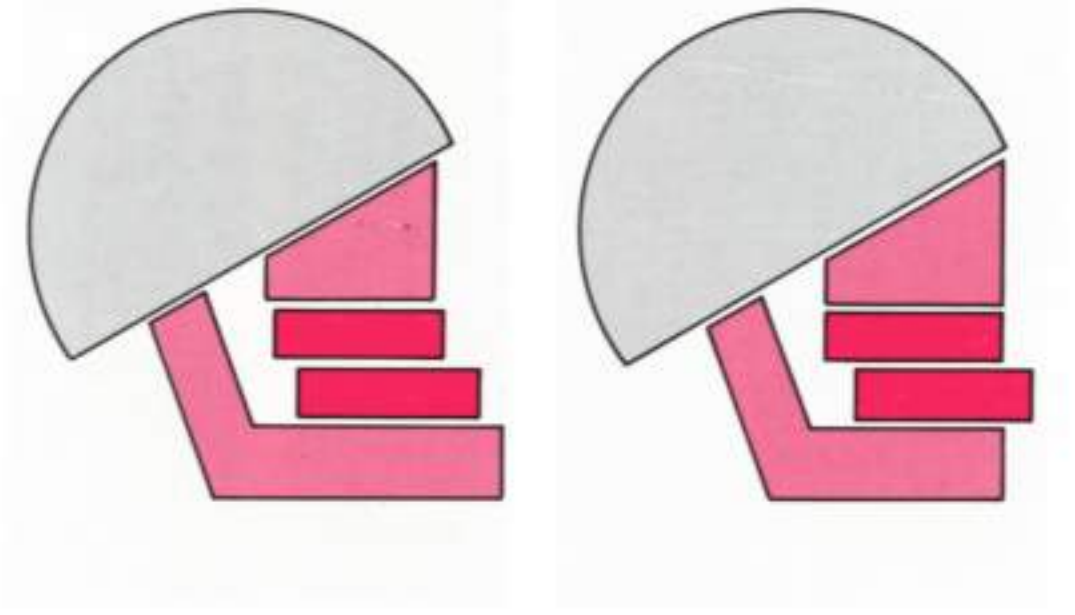




Differentiation between skeletal and dentoalveolar malocclusions (diagrammatic illustration)

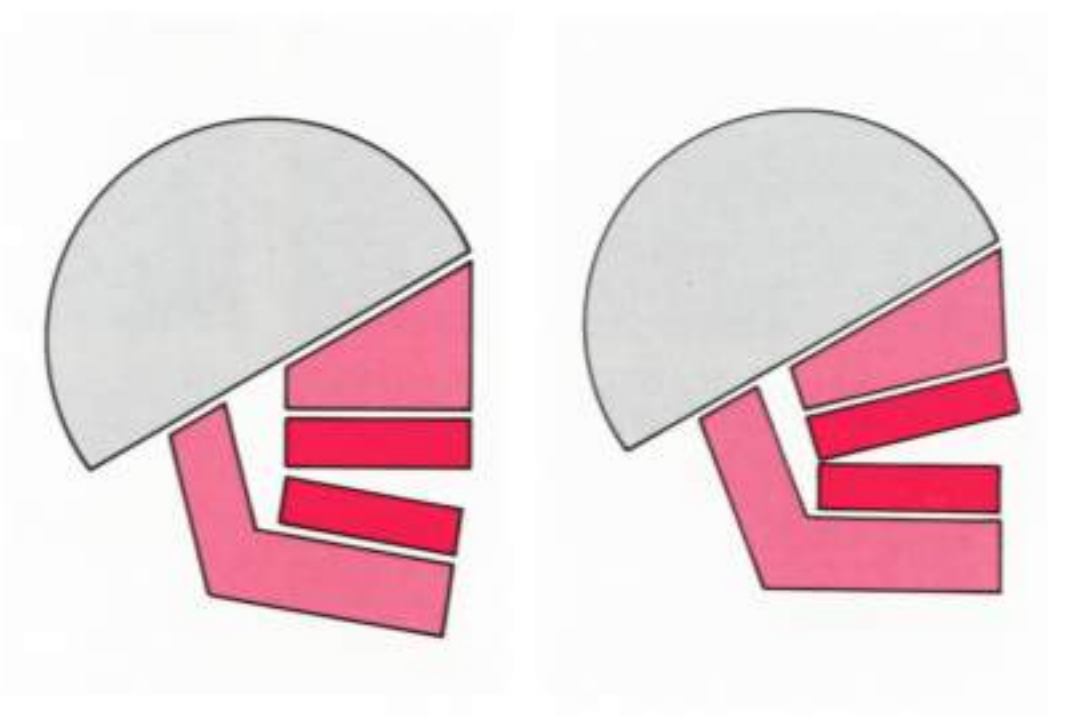
454 Class II malocclusion
Left: Skeletal Class II relationship with retrognathism of the entire mandible

Right: Dentoalveolar Class II relationship with retrusion of the mandibular alveolar process. The body of the mandible with the bony chin exhibits a normal relationship to the anterior cranial base.



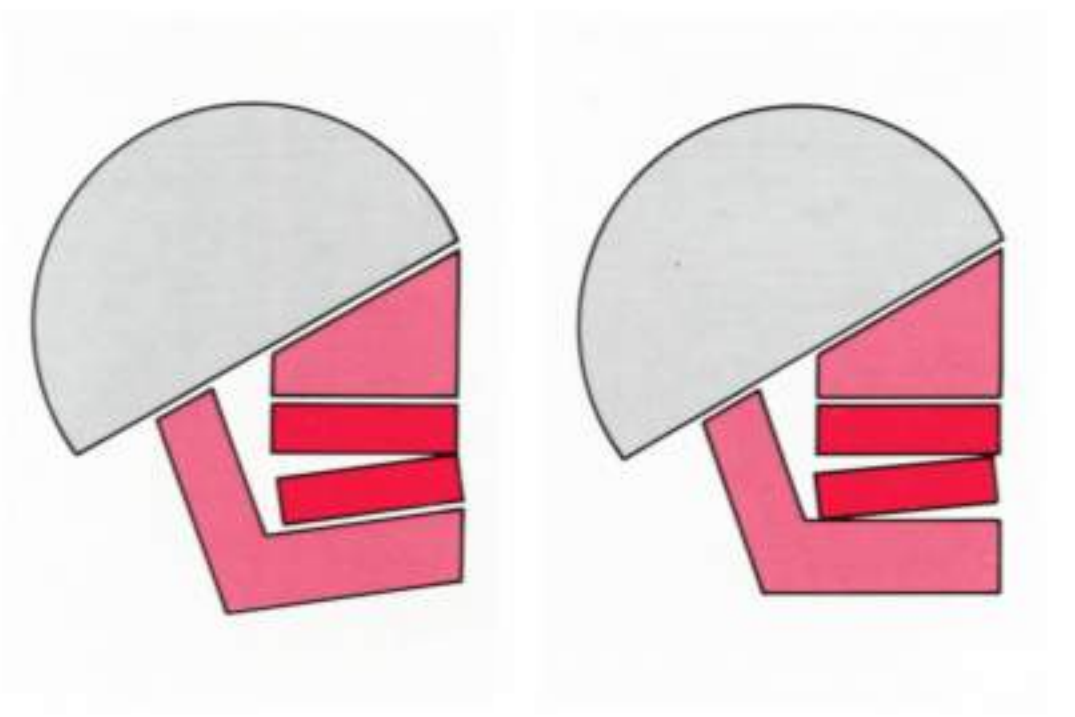
455 Class III malocclusion
Left: Skeletal Class III relationship with mandibular prognathism and maxillary deficiency to anterior cranial base.

Right: Dentoalveolar Class III, with mandibular alveolar process anteriorly positioned. Body of mandible with bony chin is correctly related to anterior cranial base.



456 Open bite malocclusion
Left: Skeletal open bite as a result of increased downward and backward inclination of the mandible. The mandibular angle is increased.

Right: Open bite of dentoalveolar origin as a result of underdevelopment anteriorly of the maxillary and mandibular alveolar processes.



457 Deep bite malocclusion
Left: Skeletal deep bite as a result of increased upward and forward inclination of the mandible. Mandibular angle is decreased.

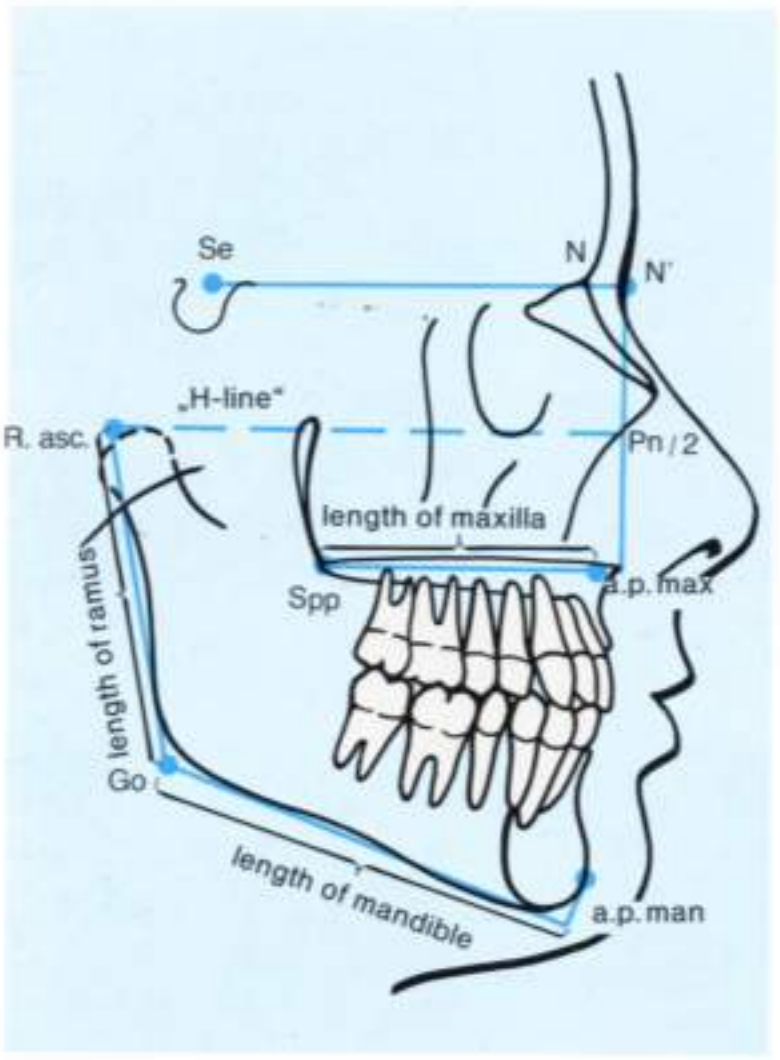
Right: Deep bite of dentoalveolar origin as a result of increased height of the mandibular alveolar process anteriorly.

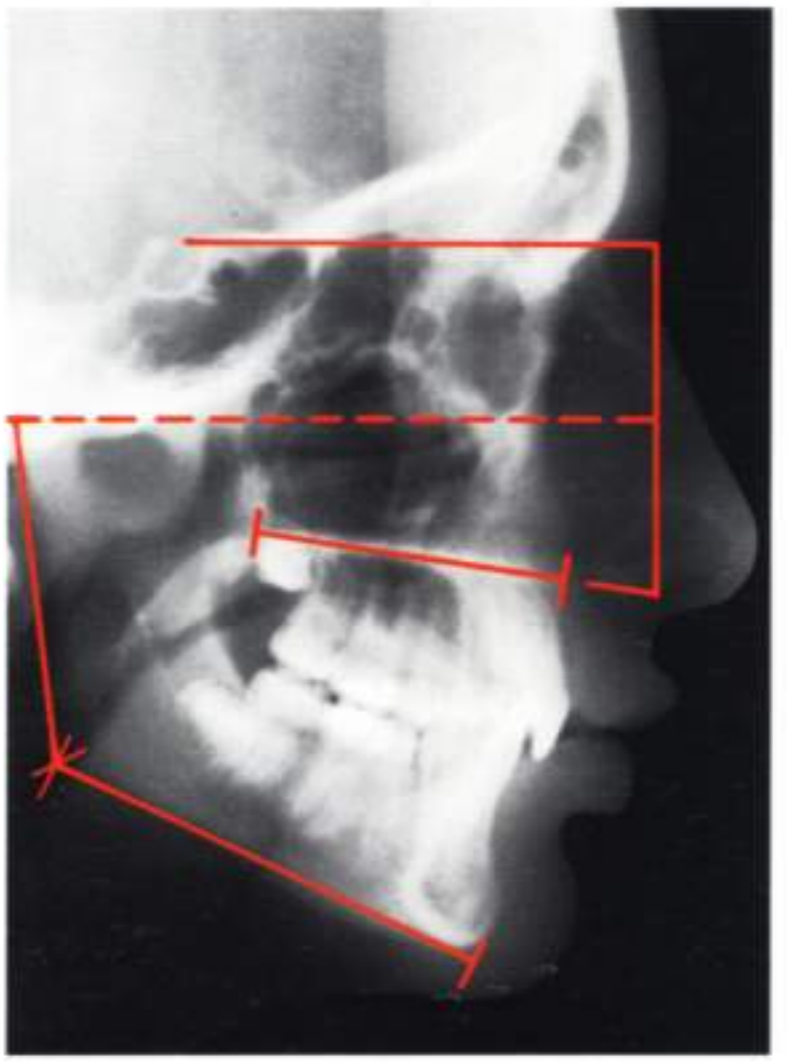
Linear Analysis of the Jaw Bases

Length of anterior cranial base
Length of mandibular base
Length of maxillary base
Length of ramus

The dimensions of the jaw bases are assessed in relationship to the N-Se distance in the form of a proportional analysis as described by A. M. Schwarz. The ideal value for the length of the mandibular base in relationship to the anterior cranial base is 3 mm greater than the N-Se distance. The relationship of upper to lower jaw base length is in the ratio of 2:3, and the average relation of the ramus to mandibular base, 5:7. Jaw base length should always be assessed in severe dysgnathias since differences within this parameter can yield important information with regard to etiology and treatment possibilities.

458 Linear analysis of the jaw bases
Se = Sella entrance
N = Nasion
N' = Soft-tissue nasion
Pn = Nasal perpendicular
FH = Ideal Frankfurt horizontal
a.p.max = Most anterior point of the maxillary base: perpendicular constructed from point A onto the palatal plane
PNS = Posterior nasal spine
a.p.man = Most anterior point of the mandibular base: perpendicular constructed from pogonion to the mandibular plane
Go = Gonion
ra. = Intersection of ramus line and Frankfurt horizontal (H-line)
Length of maxilla = a.p.max – PNS
Length of mandible = a.p.man – gonion
Length of ramus = Gonion – ra.





459 Table of measurements showing harmonious proportions between jaw bases, ramus length, and ramus width (A. M. Schwarz)
The table shows the ideal value of individual dimensions. The first calculation is to determine the ideal mandibular length which is 3 mm greater than anterior cranial base length as measured on the cephalogram (line N – Se).

The degree to which jaw base development differs from the ideal can be assessed by comparing the actual values with the ideal values.

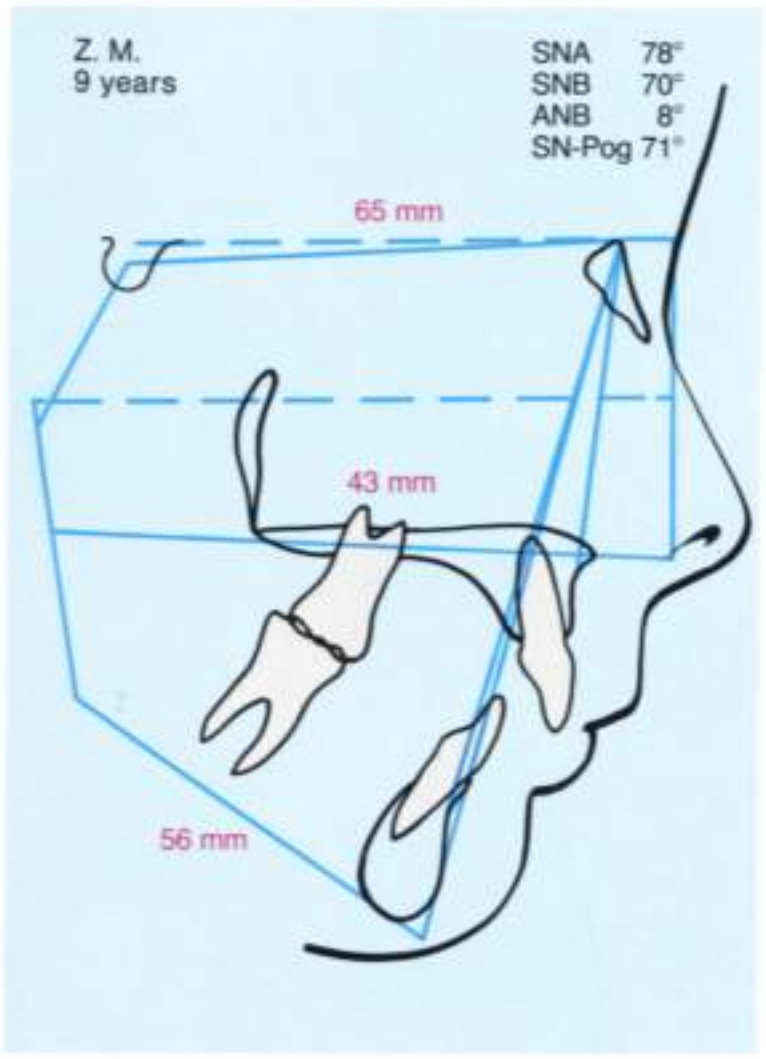
Mandible	Maxilla	Ramus length	Ramus width	Mandible	Maxilla	Ramus length	Ramus width
56	37	40	22	71	47	50.5	28
57	38	40.5	22.5	72	48	51	29
58	39	41	23	73	48.5	52	29
59	39	42	23.5	74	49	53	29.5
60	40	43	24	75	50	53.5	30
61	40.5	43.5	24	76	50.5	54	30
62	41	44	24.5	77	51	55	31
63	42	45	25	78	52	55.5	31
64	42.5	45.5	25.5	79	52.5	56	31.5
65	43	46	26	80	53	57	32
66	44	47	26	81	54	58	32
67	44.5	47.5	27	82	54.5	58.5	32.5
68	45	48	27	83	55	59	33
69	46	49	27.5	84	56	60	33.5
70	46.5	50	28	85	57	60.5	34

Class II malocclusion

460 Profile contour and development of jaw base length

Left: Soft-tissue profile contour in a 10-year-old female patient. The cephalometric analysis reveals a reduced mandibular length.

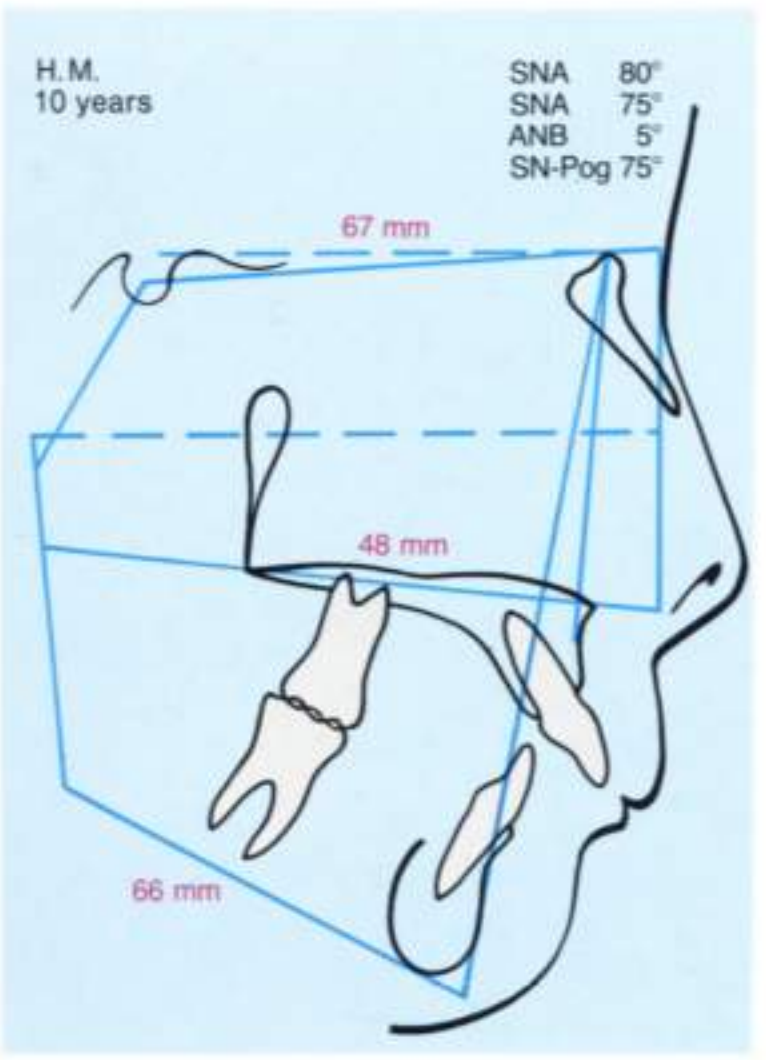
Right: Configuration in a Class II malocclusion due to an overdevelopment of the maxillary base according to the cephalometric measurements.



461 Underdevelopment of the mandible

Class II malocclusion with marked retrognathism of the mandible as a result of decreased mandibular length.

The actual length is 12 mm less than the ideal value. In contrast, the maxillary length is only slightly too short.



462 Accumulated discrepancy of maxillary and mandibular base lengths

Class II malocclusion with overdevelopment of maxillary length and underdevelopment of mandibular base.

The discrepancy between the actual and ideal values amounts to 1.5 mm in the maxilla and –4 mm in the mandible.

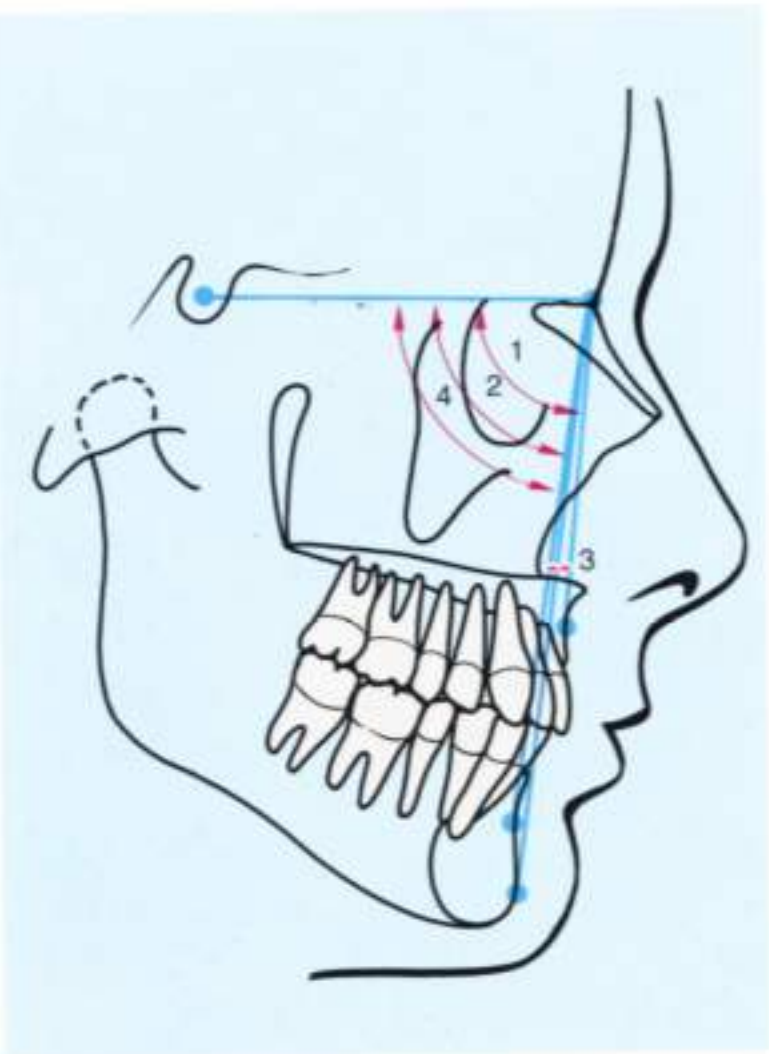
Although the discrepancy in each arch is small, when added together they reveal a marked anteroposterior malrelationship of the jaw bases.

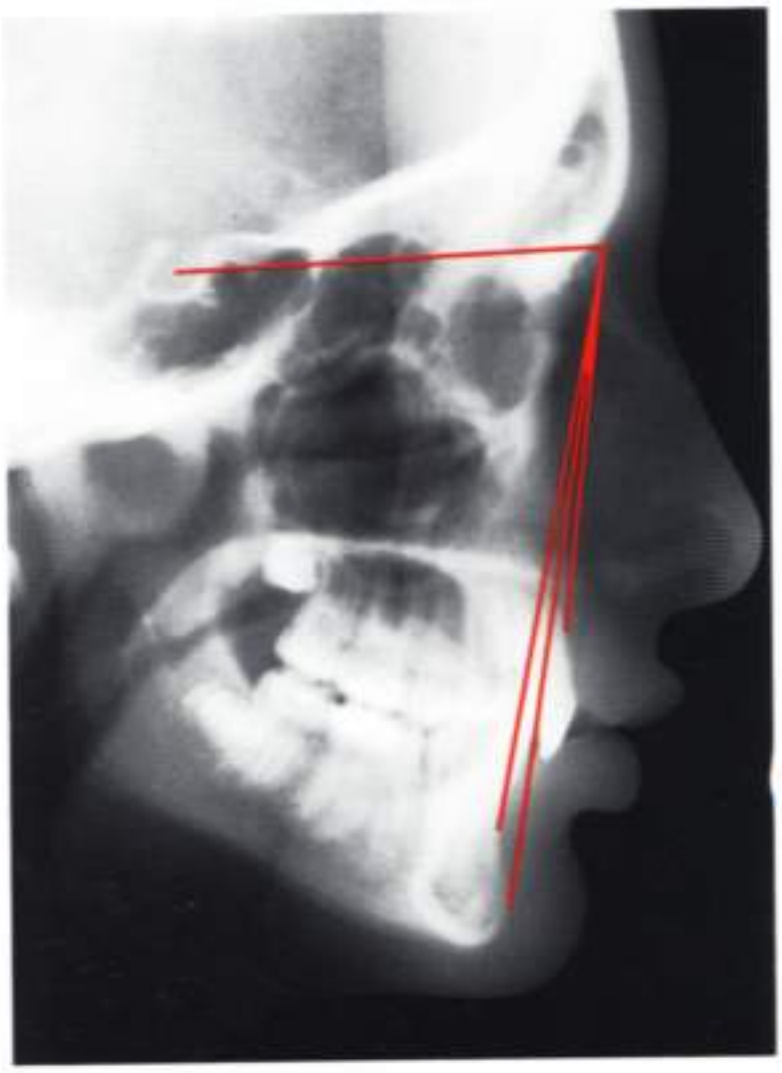
Analysis of the Skeletal Facial Profile

Angle	Definition	Clinical Standard Value
SNA	Anteroposterior position of A-point (most anterior point of the apical base in the maxilla) to anterior cranial base	81°
SNB	Anteroposterior position of B-point (most anterior point of the apical base in the mandible) to anterior cranial base	79°
ANB	Anteroposterior relationship between A-point and B-point with respect to nasion	2°
SN-Pog	Anteroposterior relationship of pogonion (basal position of mandible) to anterior cranial base	80°

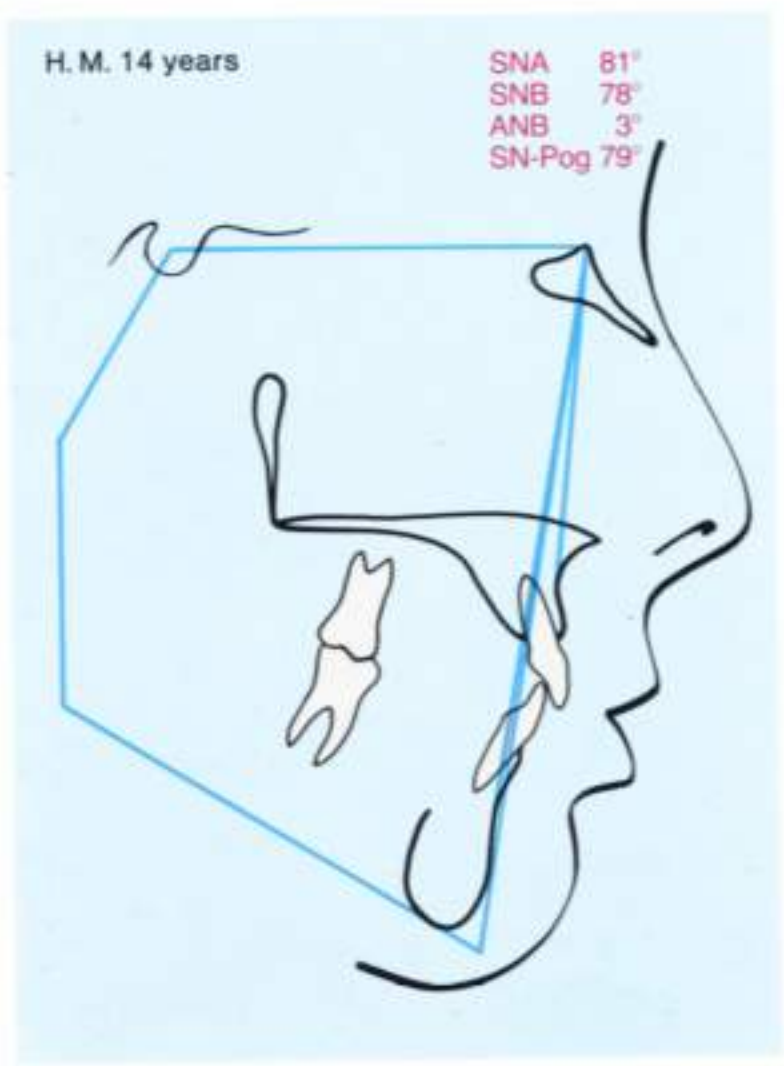
463 Anteroposterior analysis of jaw base relationships
1 = SNA angle
2 = SNB angle
3 = ANB angle
4 = SNPog angle

The anteroposterior relationships of the facial skeleton are assessed by angular measurements made from nasion to vertical reference lines.





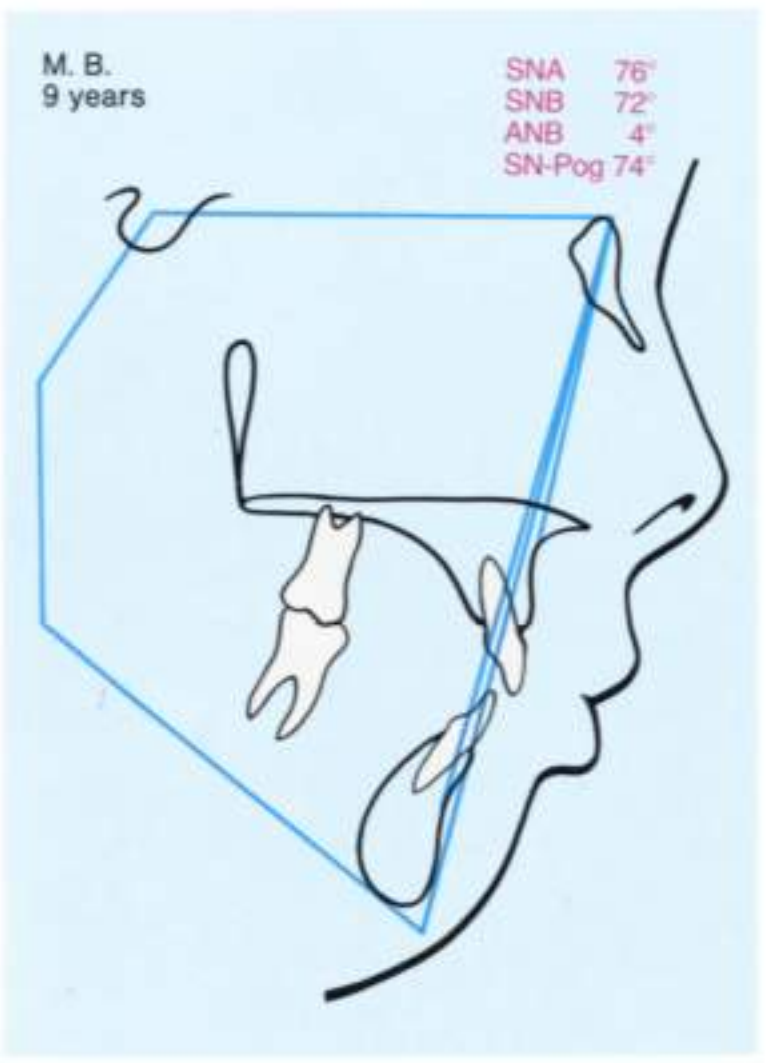
464 Orthognathic facial skeleton
The measurements which relate to the anteroposterior configuration of the jaw bases coincide with clinical standard values. In this type of configuration a skeletal Class I relationship is often present.



465 Correlation between skeletal facial profile and anteroposterior jaw relationship

Comparison of commonly encountered combinations of facial type and anteroposterior jaw relationship (ANB ∢).

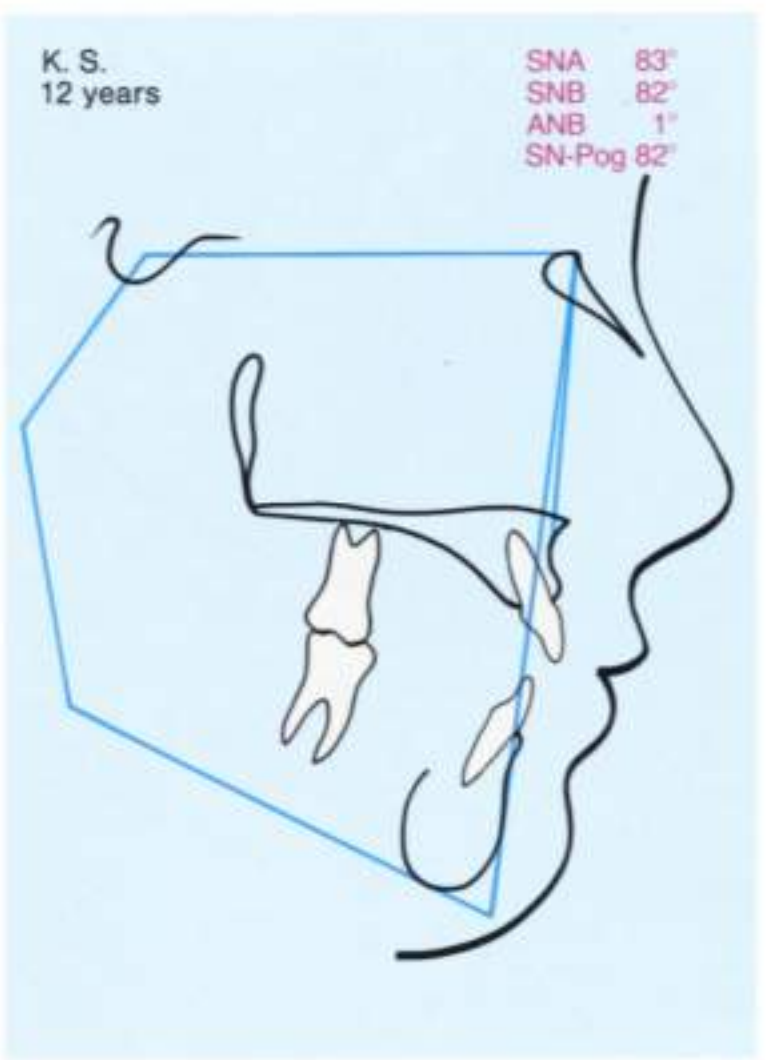
There is no close correlation between the anteroposterior facial morphology and the skeletal maxillomandibular discrepancy. Dysgnathias and ideal occlusal relationships occur in all facial types.



466 Retrognathic facial pattern

The jaw bases are posterior in relation to anterior cranial base. This physiologic variable in anteroposterior facial type is often combined with a skeletal Class II relationship.

Treatment of distoclusion in a retrognathic facial type is more difficult, and the prognosis less favorable, than the same malocclusion in an orthognathic facial type.



467 Prognathic facial pattern

With respect to standard values, the maxillary and mandibular bases are anterior to the facial skeleton.

In this type of facial profile a Class III malocclusion is often present.

Vertical Analysis of the Facial Skeleton

Measurement	Definition	Clinical Standard Value
Sum of posterior angles	Sum of sella (NSar), articular (SarGo) and gonial angle (arGoMe) according to Björk	394°±6
Go_1 ∢	Upper gonial angle (NGoar) according to Jarabak	52°–55°
Go_2 ∢	Lower gonial angle (NGoMe) according to Jarabak	70°–75°
SN–MeGo ∢	Angle between anterior cranial base (SN) and the mandibular line (MeGo) according to Schudy	34°
Pal–MeGo ∢	Angle between the maxillary line (Pal) and mandibular line (basal plane angle). The measurement is influenced by changes in the inclination angle.	25°

468 Vertical analysis of the facial skeleton
Diagrammatic illustration of the angular and linear measurements.

1 = Sella angle (NSar ∢)

2 = Articular angle (SarGo ∢)

3 = Gonial angle (arGoMe ∢)

4 = Upper gonial angle (NGoar ∢)

5 = Lower gonial angle (NGoMe ∢)

6 = Angle between anterior cranial base (SN) and mandibular plane (MeGo) (NS-MeGo ∢)

7 = Basal plane angle (Pal-MeGo ∢)

8 = Inclination angle according to *A. M. Schwarz* (I ∢)

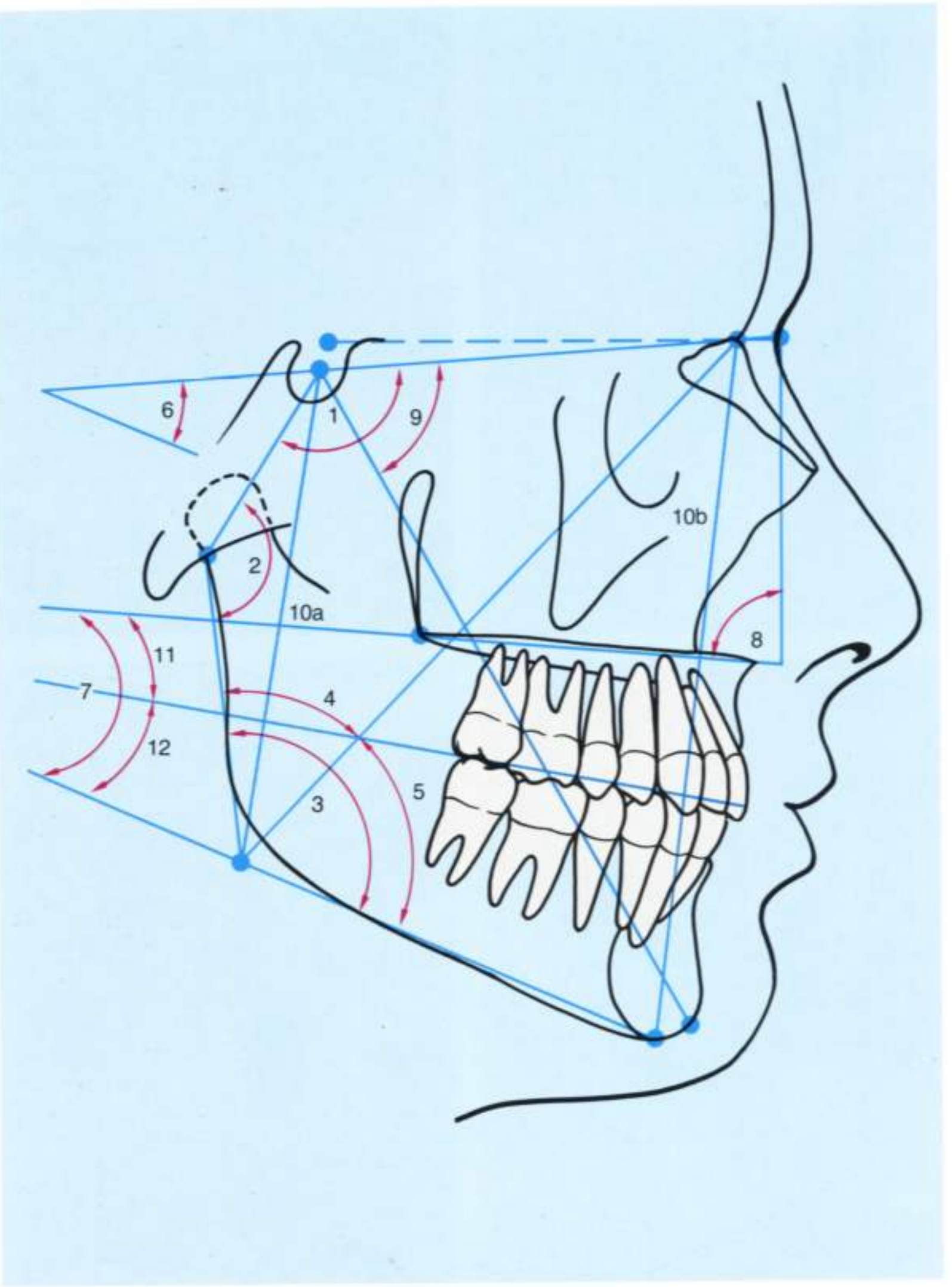
9 = Angle between Y-axis (SGn) and anterior cranial base (SN)

10a = Posterior facial height (SGo)

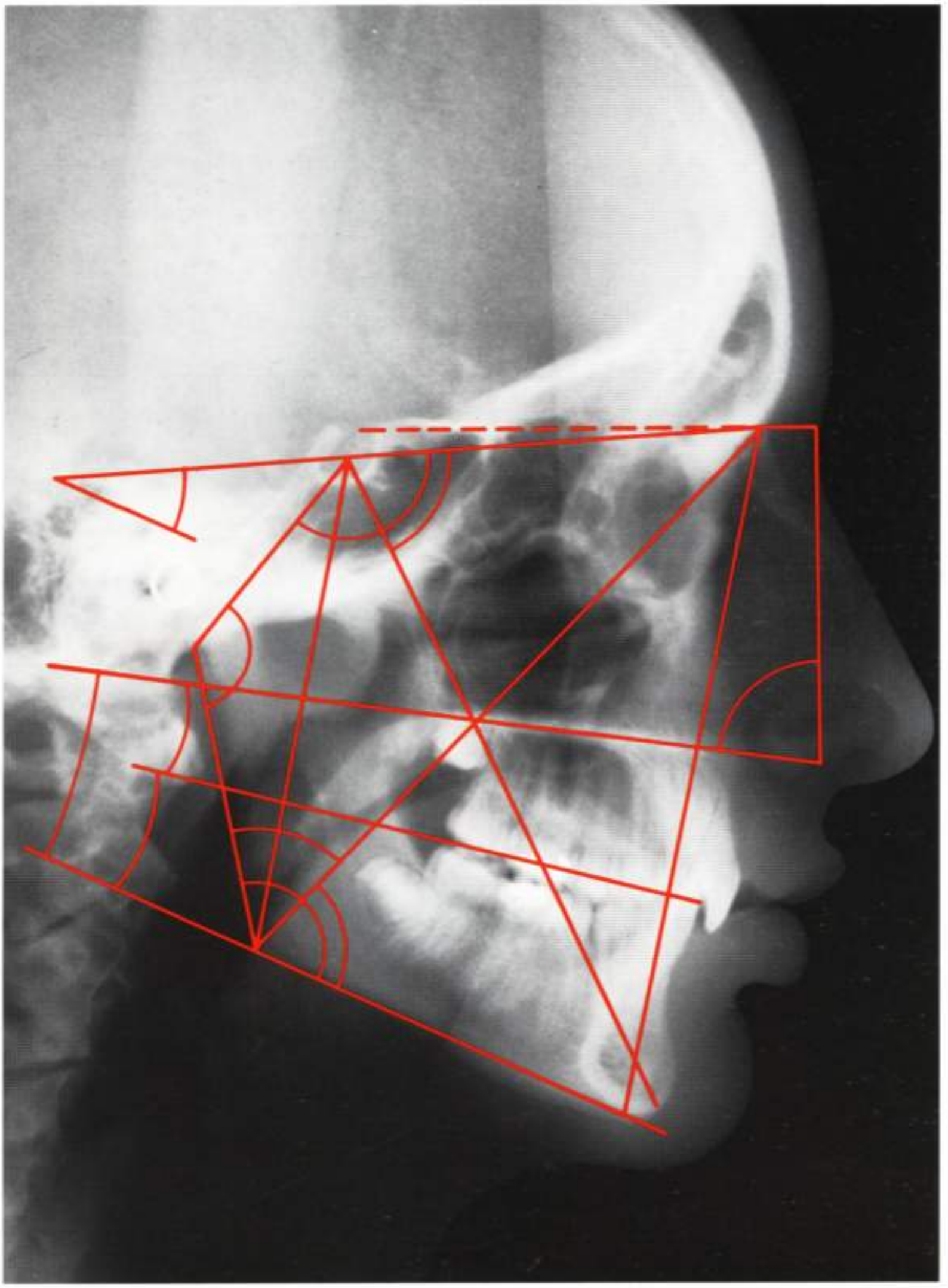
10b = Anterior facial height (NMe)

11 = Angle between occlusal plane (OcP) and maxillary plane (Pal)

12 = Angle between occlusal plane (OcP) and mandibular plane (MeGo).



Measurement	Definition	Clinical Standard Value
I ∢	Inclination angle according to A. M. Schwarz; the angle between the Pn-perpendicular line and the maxillary line (Pal)	85°
SN–Gn ∢	(Y-axis) The angle between the anterior cranial base (SN) and the most anteroposterior point of the bony chin (gnathion) in the center of the sella	66°
SGo: NMe %	Percentage ratio between the posterior (SGo) and the anterior facial height (NMe) according to Jarabak	62–65 %
Pal–OcP ∢	The angle between maxillary plane and the occlusal plane (OcP)	11°
MeGo–OcP ∢	Angle between mandibular plane (MeGo) and the occlusal plane	14°



Tracing of measurements on the lateral cephalogram.

Growth Direction – Rotation of the Mandible

Types of rotation in relation to anterior cranial base:

Parallel displacement	=	Neutral growth type
Forward rotation	=	Horizontal growth type
Backward rotation	=	Vertical growth type

The displacement of the mandible in relation to the anterior cranial base, in particular, mandibular rotation is growth-related; its direction is stabilized by approximately the 9th year of age. It is dependent on the relationship between the *growth rates* in the *posterior* (condylar growth) and the *anterior* (sutural-alveolar growth) regions of the facial skeleton. With a neutral i.e. average growth direction, the growth increments between both areas are balanced. In the horizontal type, condylar growth dominates, whereas in vertical growth types, sutural-alveolar growth is increased compared to the condylar region.

469 Horizontal and vertical rotation of the mandible

Red = Horizontal rotation
Blue = Vertical rotation

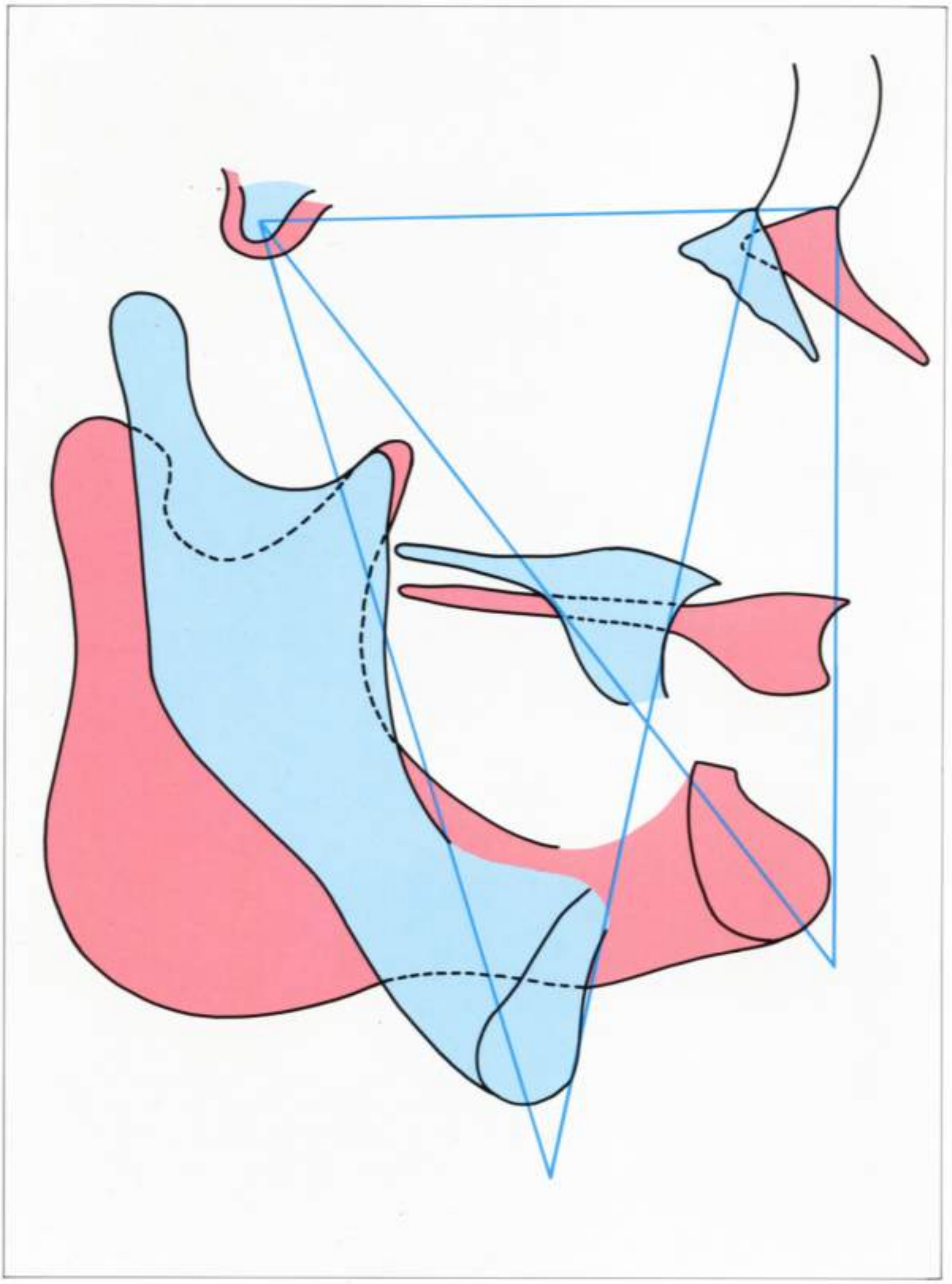
Tracing of anterior cranial base line, of the NPog-line, and of the Y-axis.

With increased horizontal rotation of the mandible, the difference in length between anterior and posterior facial height is decreased. The ramus is long and wide. The mandibular symphysis is thick and the base of the body of the mandible is high.
In case of vertical rotation of the mandible in relation to the anterior cranial base, development of the anterior facial height is disproportionately greater. The morphology of this facial type shows the following characteristics: a short and narrow ramus, a small mandibular base, and a thin symphysis.

In cases of horizontal rotation of the mandible there is upward and forward rotation during the growth period (*horizontal growth pattern*). In the case of the vertical morphology the downward and backward rotation of the mandible increases (*vertical growth pattern*).

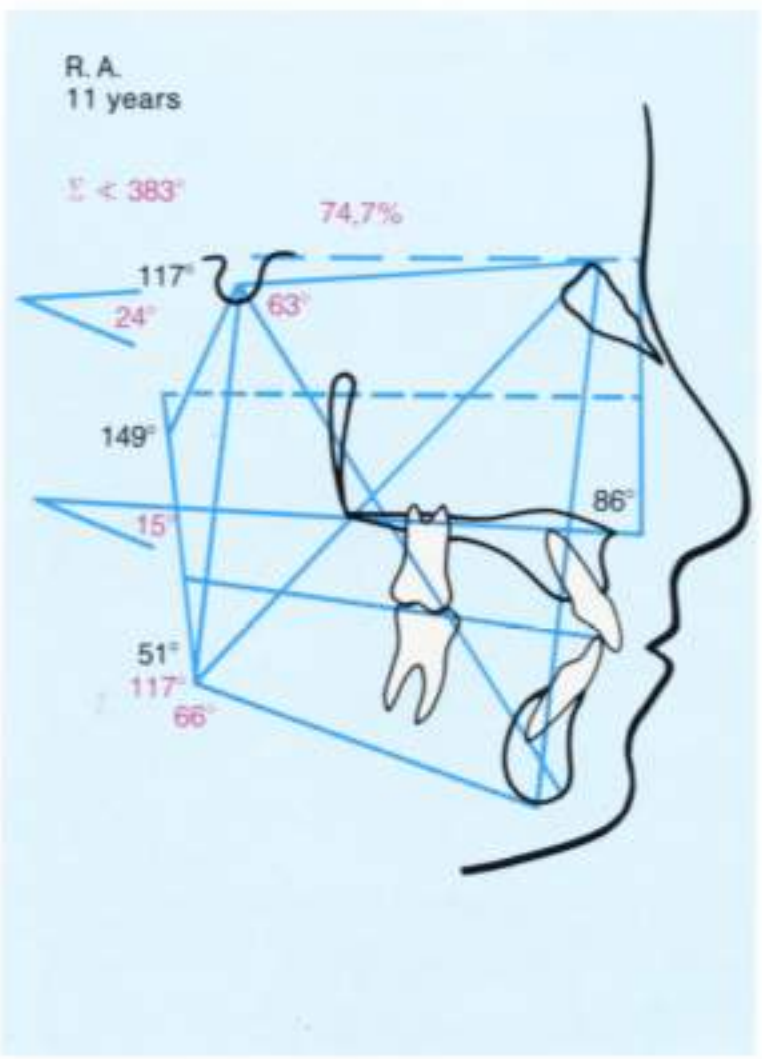
A predisposition to deep bite exists in the case of a horizontal growth type, the tendency to an open bite in the vertical growth type.

For the assessment of the facial type, as well as the classification of the anteroposterior jaw discrepancy, the analysis of vertical relationship should be included. As the direction of growth of the mandible with respect to the anterior cranial base and to the maxilla may show marked differences and thus exerts a divergent influence on occlusal relationships. The rotation of the mandible can be influenced by dentofacial orthopedic therapy.



470 Mandibular rotation and facial profile
The reduced lower face height is characteristic for the profile contour in a patient with enhanced horizontal mandibular rotation.

Right: The lower face hight is long in excessive vertical rotation.

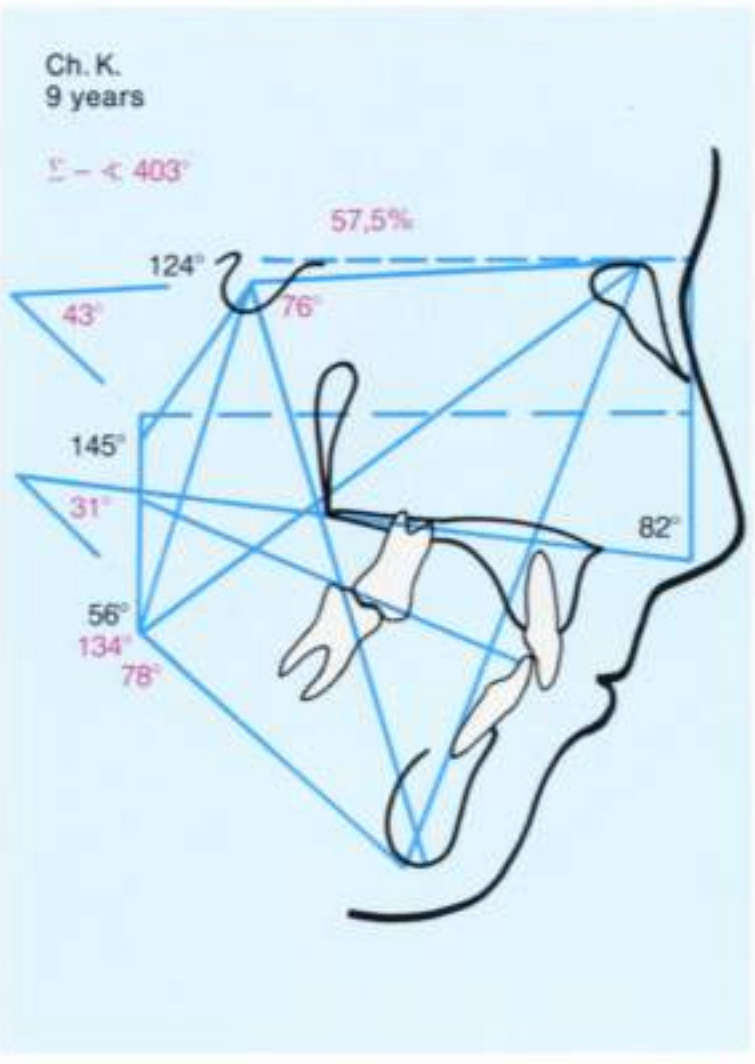


471 Cephalometric findings in horizontal mandibular rotation
In this skeletal facial configuration, all measurements which relate to the position of the mandible in relation to the anterior cranial base are smaller than the standard values: Sum of posterior angles, gonial angle, NGoMe angle, basal plane angle, SN-MeGo angle, angle of the Y-axis.

The percentage ratio between anterior and posterior facial height is larger than the standard values.

The horizontal reference lines of the analysis seem nearly parallel to each other.

Right: Original radiograph of the tracing.



472 Cephalometric findings in vertical mandibular rotation
In an increased downward and backward rotation of the mandible, the angular measurements which outline the relationship of the vertical position of the mandible to the anterior cranial base are increased in relation to standard values. The percentage ratio of facial height is decreased. The cant of the mandibular plane is steeper than normal in relation to the other horizontal reference planes.

Right: Original radiograph of the tracing.

Rotation of the Maxillary Base

Classification of rotation of the maxilla in relation to the anterior cranial base, according to A. M. Schwarz:

Normalinclination:	I ∢ = 85°
Anteinclination:	I ∢ => 85°
Retroinclination:	I ∢ =< 85°

The *inclination angle* records the rotation of the maxillary base to the anterior cranial base, i.e. to the N-Se-line as described by A. M. Schwarz. The angle is not measured directly but is defined as the angle between the Pn-perpendicular and the palatal plane (Pal). With *anteinclination* there is a forward maxillary rotation; with *retroinclination* there is a backward rotation of the maxilla. The maxillary inclination influences the clinical appearance of the anterior tooth position. It can be changed by dentofacial orthopedic treatment.

473 Anterior and posterior rotation of the maxilla

Red = Anterior rotation
Blue = Posterior rotation

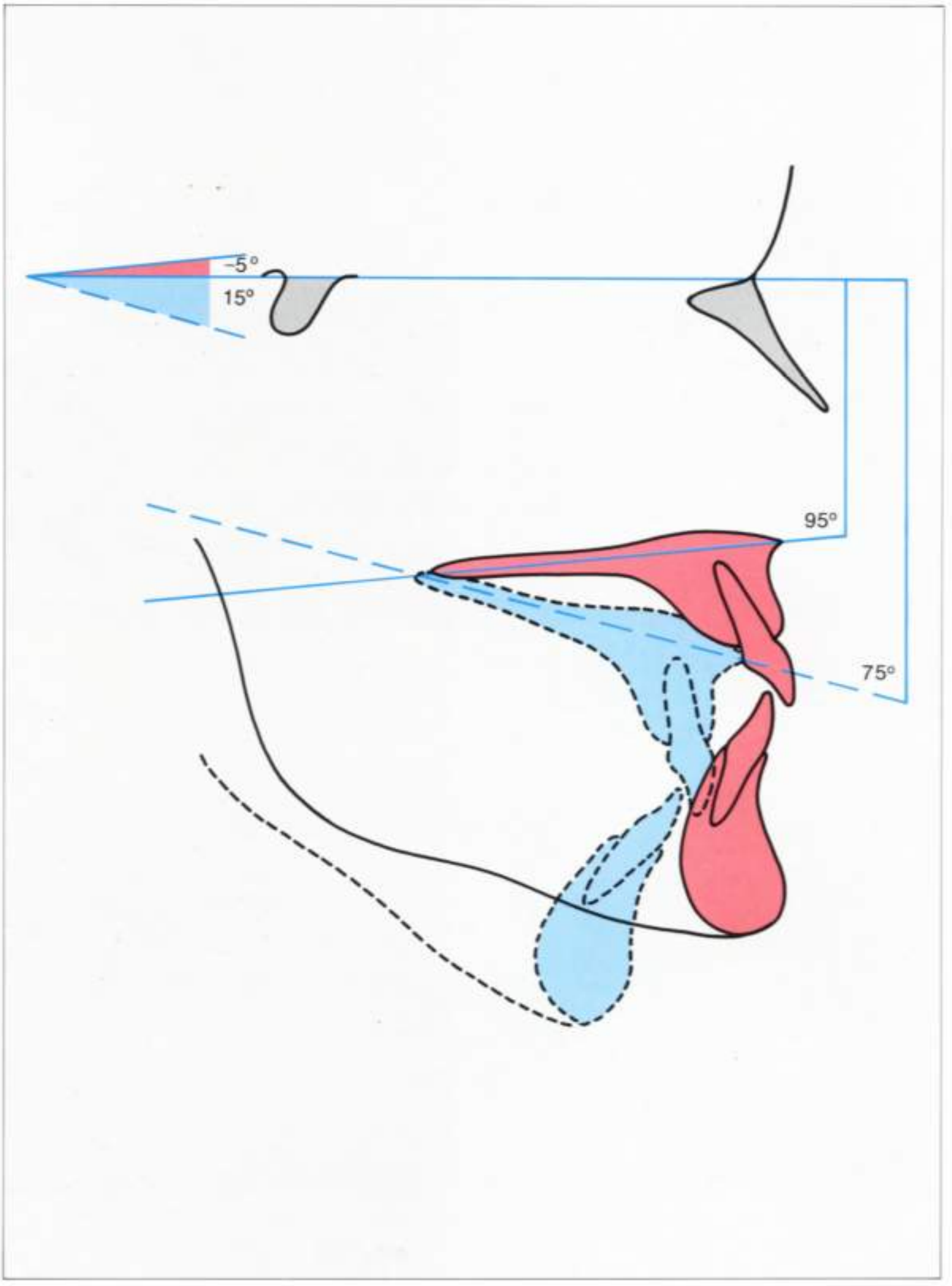
Tracing of reference lines to determine the position of the maxilla according to *A. M. Schwarz:* the plane of the anterior cranial base (N-Se), the Pn-perpendicular, and the palatal plane.

Marking of the inclination angle and of the angle between the N-Se line and the palatal plane.

In cases of anterior rotation of the maxilla, as compared with the clinical standard values (anteinclination), the angle between the palatal plane and the Pn-perpendicular is increased. The anteinclination of the maxilla is correlated with anterior rotation of the jaw bases, and results in a labial positioning of the upper anterior teeth.

In cases of posterior rotation of the maxilla (retroinclination) the inclination angle as compared with the standard value is decreased. In this type of maxillary displacement the jaw bases are translated posteriorly and the axial inclination of the upper incisors appears to be tipped lingually.

The maxillary inclination to the anterior cranial base can be influenced by dentofacial orthopedic treatment.

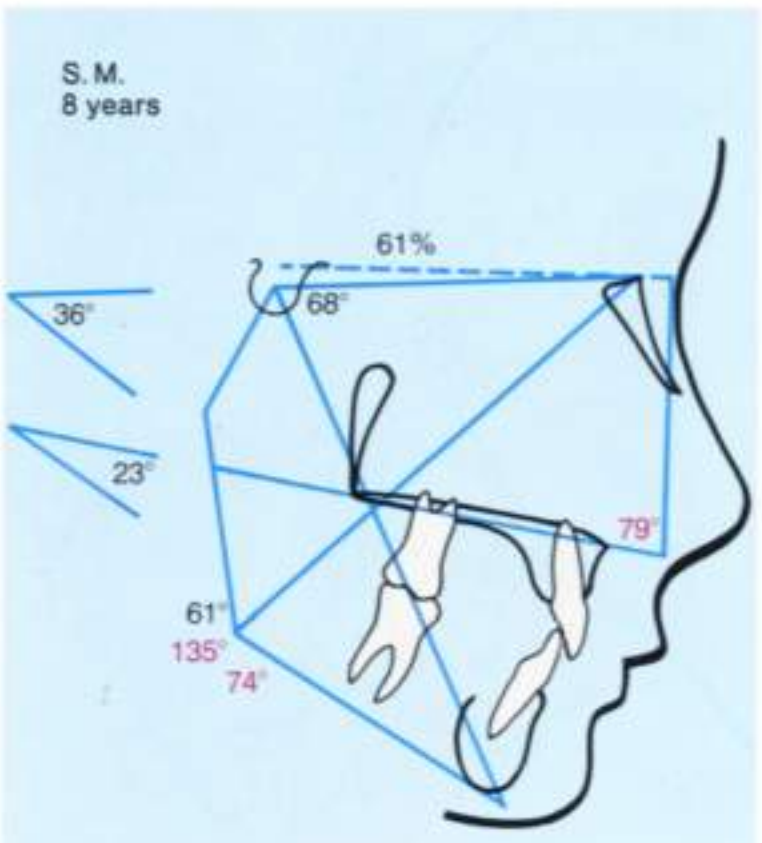


474 Maxillary inclination and occlusal findings

Maxillary rotation influences the amount of overbite and the clinical appearance of the inclination of the upper anterior teeth.

Left: Maxillary retroinclination with increased overbite and the clinical picture of lingually tipped upper anterior teeth.

Right: Maxillary anteinclination with reduced overbite and the clinical picture of labially inclined upper incisor teeth.



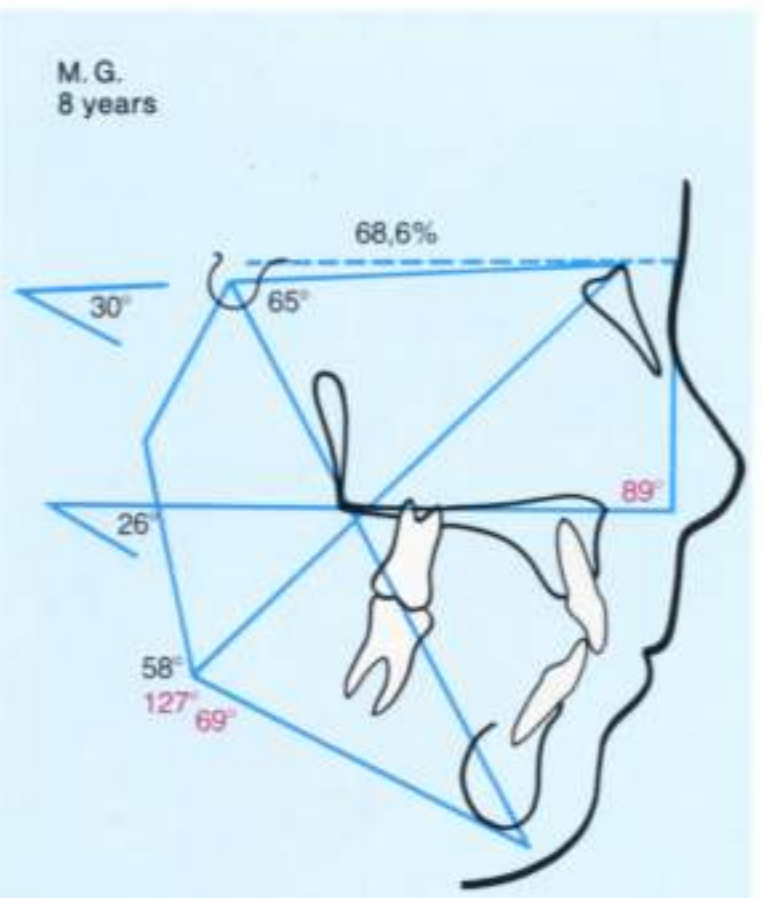
Mandibular growth pattern and maxillary inclination

475 Cephalometric findings in maxillary retroinclination

The inclination angle is not correlated to the mandibular growth pattern.

Left: Vertical rotation of the mandible, combined with maxillary retroinclination. The effect of the increased mandibular downward and backward rotation on the occlusal relationship is compensated by the posteriorly directed maxillary rotation. This compensation is reflected by the size of the basal plane angle. Maxillary inclination has always to be taken into account when analyzing the basal plane angle.

Right: Original radiograph of the tracing.



476 Cephalometric findings in maxillary anteinclination

Left: Horizontal mandibular rotation combined with maxillary anteinclination.

The anterior rotation of the maxilla compensates the tendency to deep bite, caused by the mandibular rotation. The measurement of the basal plane angle correlates closely with the standard value on account of the opposite rotation of the maxilla and mandible.

Right: Original radiograph of the tracing.

Combinations of Maxillary and Mandibular Rotation

Types of maxillary and mandibular rotations:

- Convergent rotation of the jaw bases
- Divergent rotation of the jaw bases
- Upward rotation of both jaw bases
- Downward rotation of both jaw bases

Combination of the maxillary and mandibular rotation determines the degree of the anterior overbite.

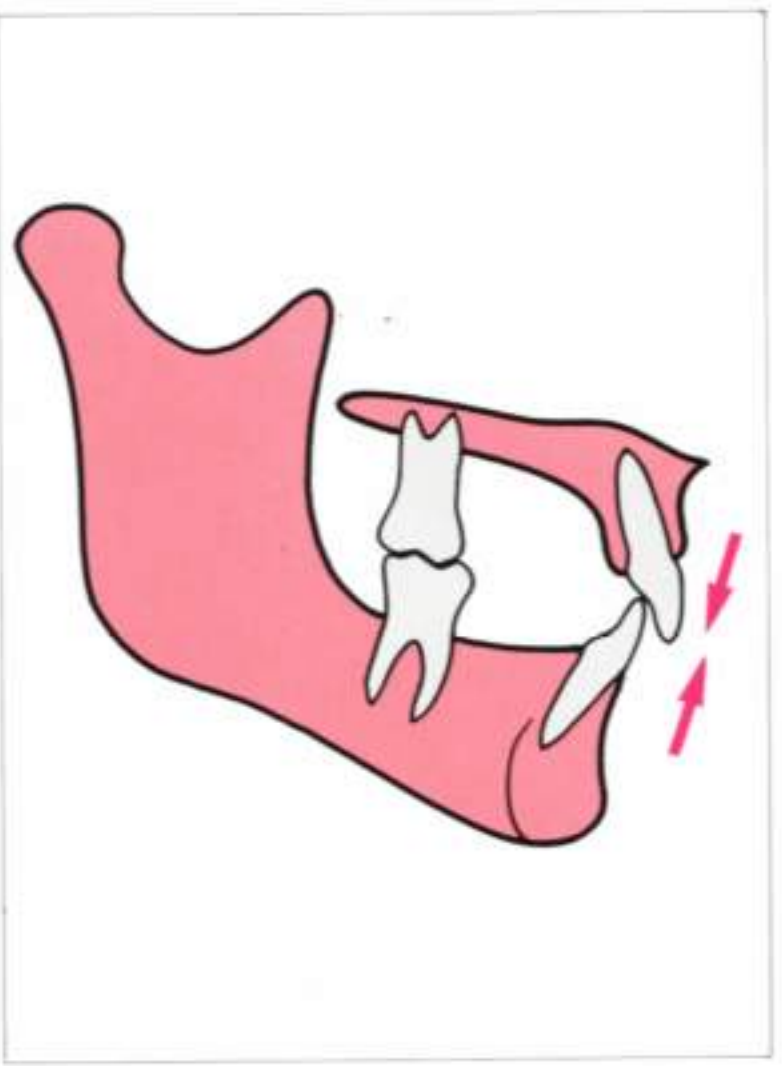
When jaw bases are rotated equivalently in the *same direction* (upward or downward), the vertical dimension during growth remains constant. If one of the rotations is greater, the result is either bite opening or bite closing. The *convergent* rotation results in a deep bite, the *divergent* rotation leads to an open bite. Dentofacial orthopedic treatment of the vertical discrepancy is very difficult in these rotations of the jaw bases in opposite directions.

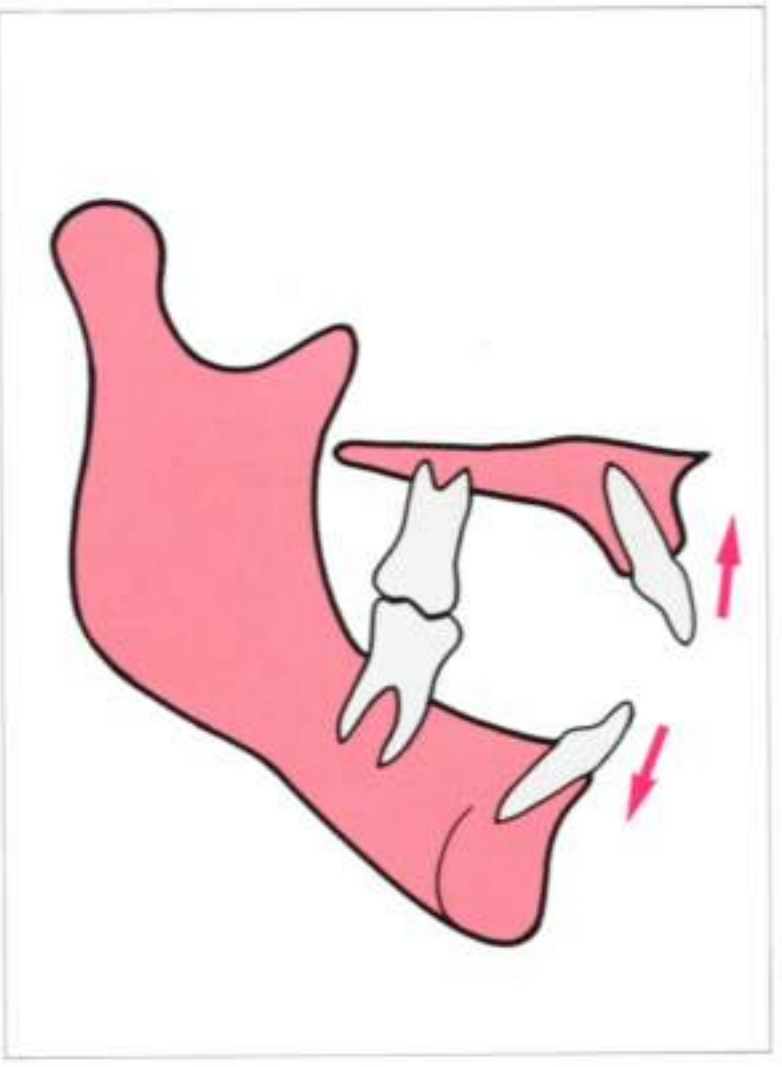
Rotation of the jaw bases

477 Convergent and divergent rotation

The convergent rotation of the jaw bases during the growth period results in a deep bite which is very difficult to correct.

Right: In a skeletal open bite, a divergent rotation of the jaw bases is often present.

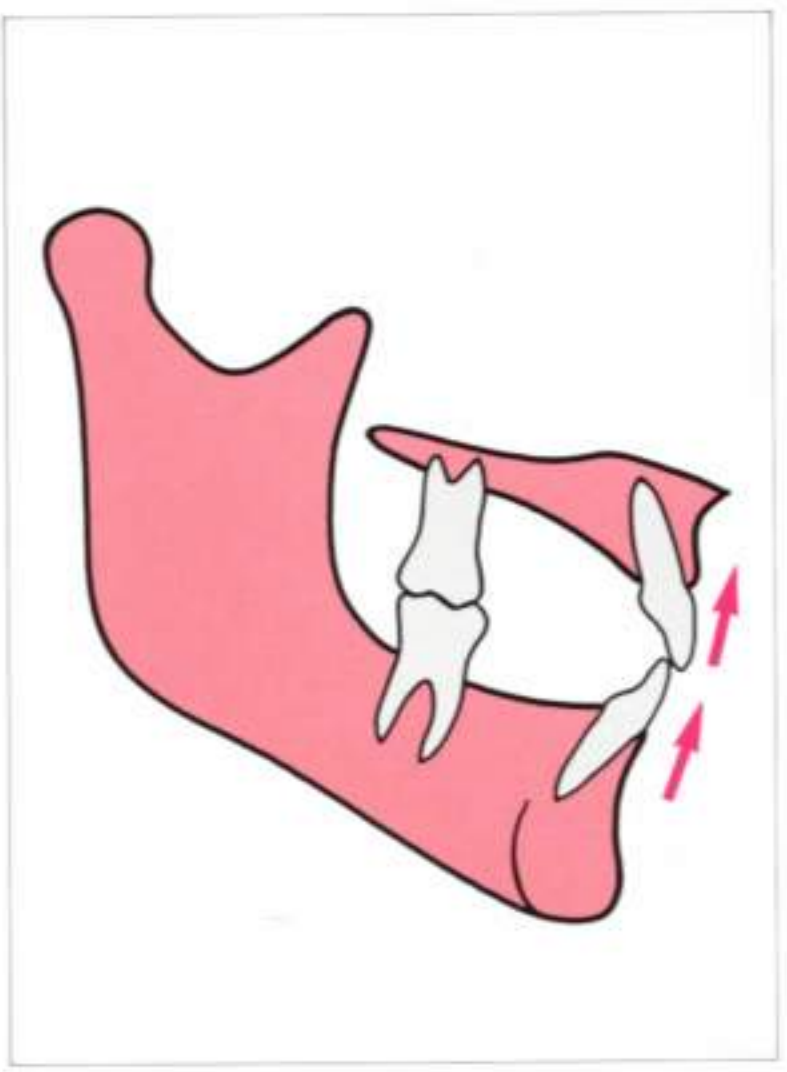


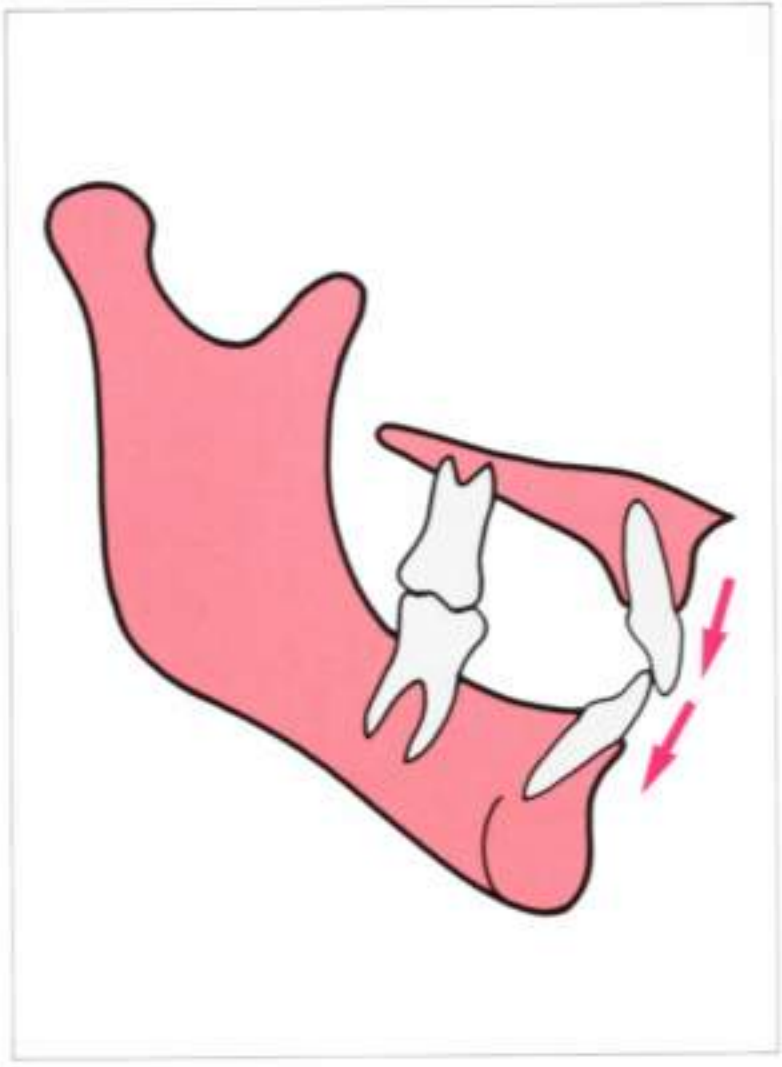


478 Rotation in the same direction

In a cranially directed rotation of both jaw bases, an increased upward and forward rotation of the mandible can be compensated by an anteinclination of the maxilla.

Right: In an inferiorly directed rotation of both jaw bases, an increased downward and backward rotation of the mandible can be compensated by a retroinclination of the maxilla.

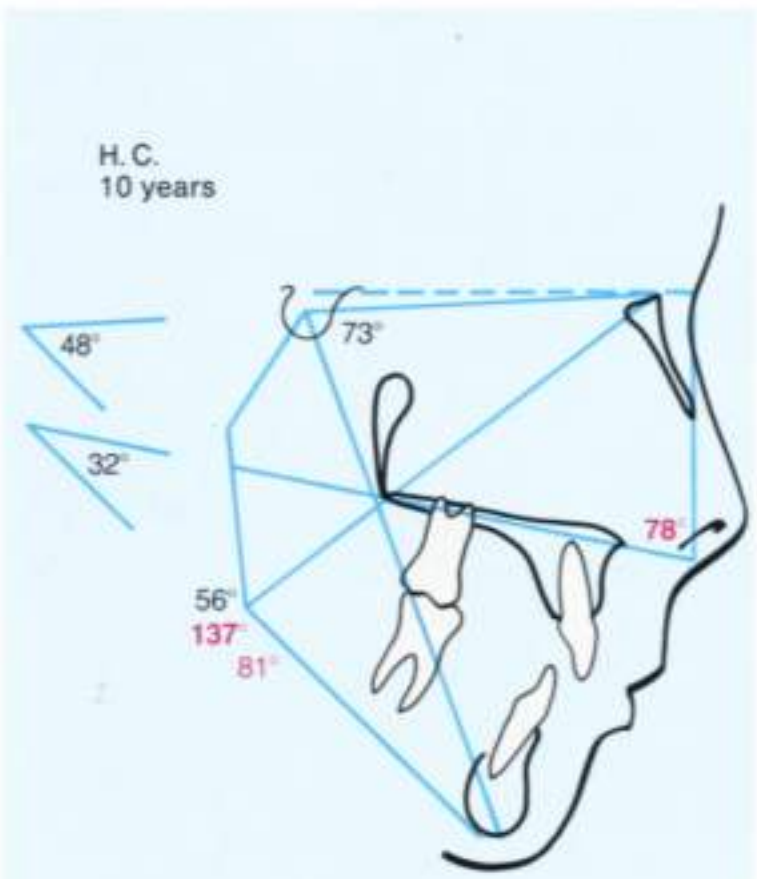




479 Occlusal relationship and rotation of jaw bases
Combination of maxillary and mandibular rotation is of importance for the occlusal relationships.

Left: The tendency to an open bite in a marked vertical mandibular rotation is compensated by maxillary retroinclination (see Fig. 480).

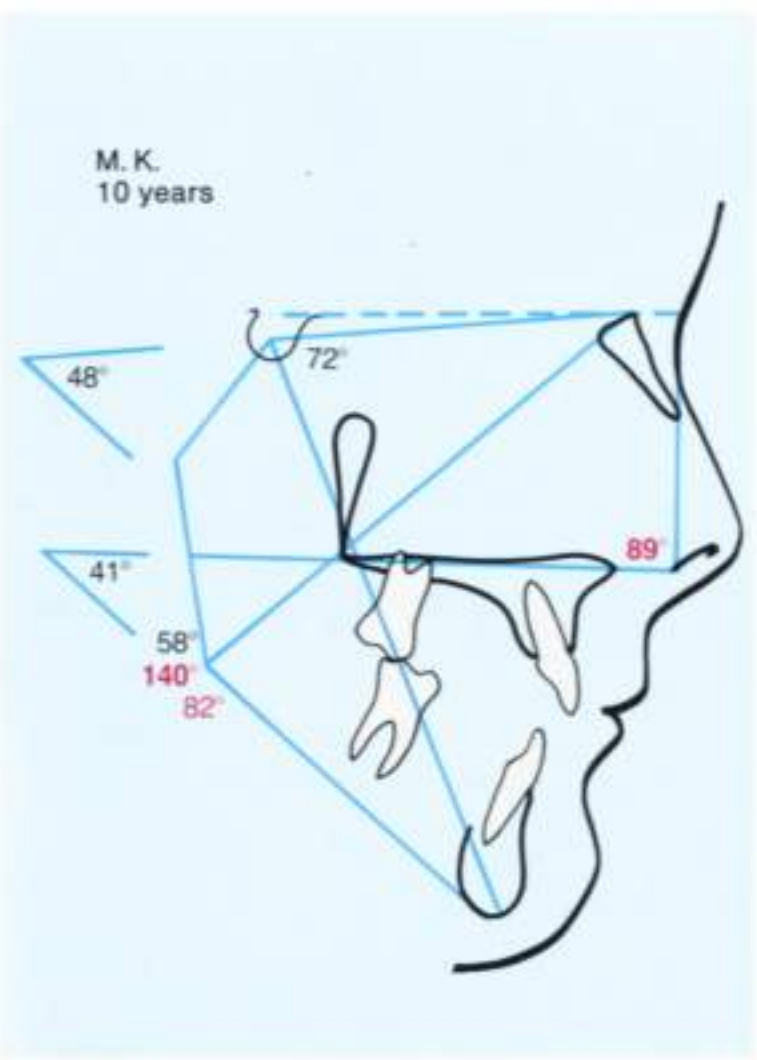
Right: The divergent rotation of both jaw bases results in an open bite (see Fig. 481).



480 Cephalometric findings in downward rotation of the jaw bases
Left: Tracing of the lateral cephalogram showing the relevant measurements. The increased downward and backward rotation of the mandible is compensated by rotation of the maxilla in the same direction.

Right: The original cephalometric radiograph.

The occlusal relation of this female patient is on the left side of Fig. 479.



481 Cephalometric findings in divergent rotation of the jaw bases
Left: The measurements of the tracing of the cephalometric radiograph signify a skeletal open bite with vertical mandibular rotation, aggravated by the maxillary anteinclination.

Right: The original lateral headfilm.

Fig. 479 (right) shows the occlusal relationship of this female patient.

Analysis of Incisor Position

Measurement	Definition	Clinical Standard Value
$\underline{1}$ – SN ∢	Angle between long axis $\underline{1}$ and anterior cranial base	102 ° ± 2
$\underline{1}$ – Pal ∢	Angle between long axis $\underline{1}$ and the palatal plane (Pal) according to A. M. Schwarz	70 ° ± 5
$\overline{1}$ – MeGo ∢	Angle between long axis $\overline{1}$ and the mandibular plane (MeGo)	90 ° ± 3
JJ ∢	Interincisal angle between the long axes of upper and lower incisors	135 °
$\underline{1}$ – N-Pog	Distance of incisal edge $\underline{1}$ to the N-Pog-line	+2 – +4 mm
$\overline{1}$ – N-Pog	Distance of incisal edge $\overline{1}$ to the N-Pog-line	−2 – +2 mm

482 Analysis of incisor position

Left: Tracing of angular measurements.

1 = Angle of long axis of upper central incisors (Is $\underline{1}$- Ap $\underline{1}$) to the anterior cranial base

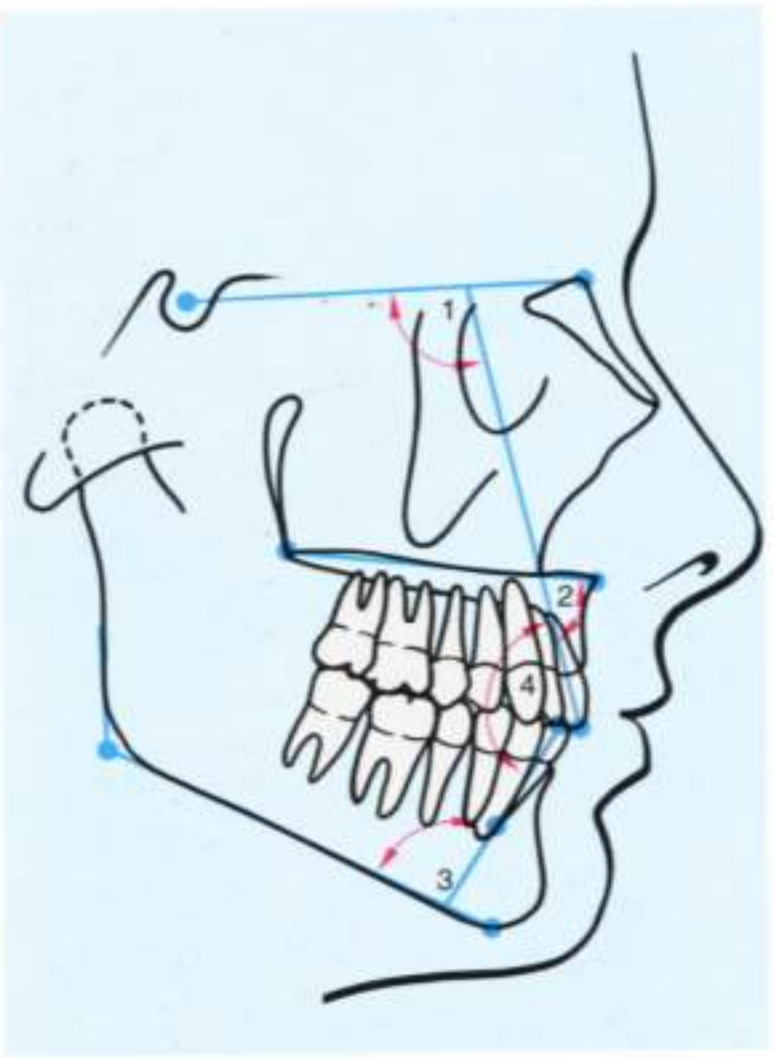
2 = Angle of long axis of upper central incisors to palatal plane

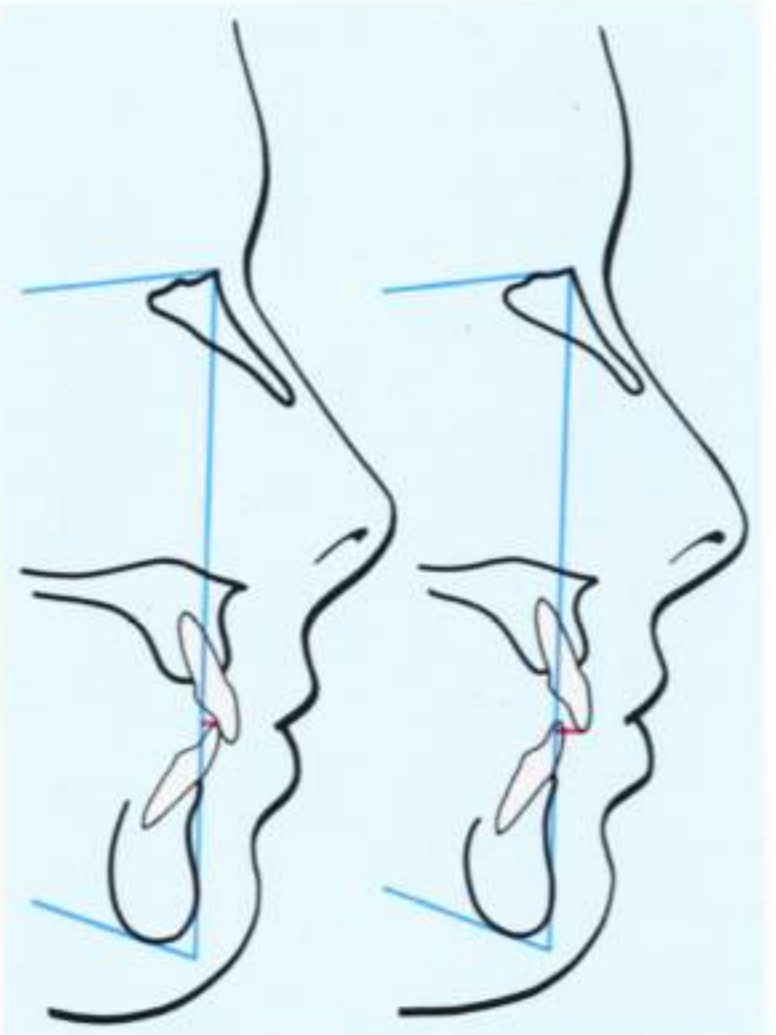
3 = Angle of long axis of lower central incisor (Is $\underline{1}$- Ap $\underline{1}$) to the mandibular basal plane

4 = Interincisal angle (JJ ∢)

Right: Tracing of linear measurements. Outer: Tracing of the perpendicular from the N-Pog-line to the incisal edge of the most anteriorly positioned upper central incisor.

Center: Tracing of the perpendicular from the N-Pog-line to the incisal edge of the anterior – most lower central incisor.



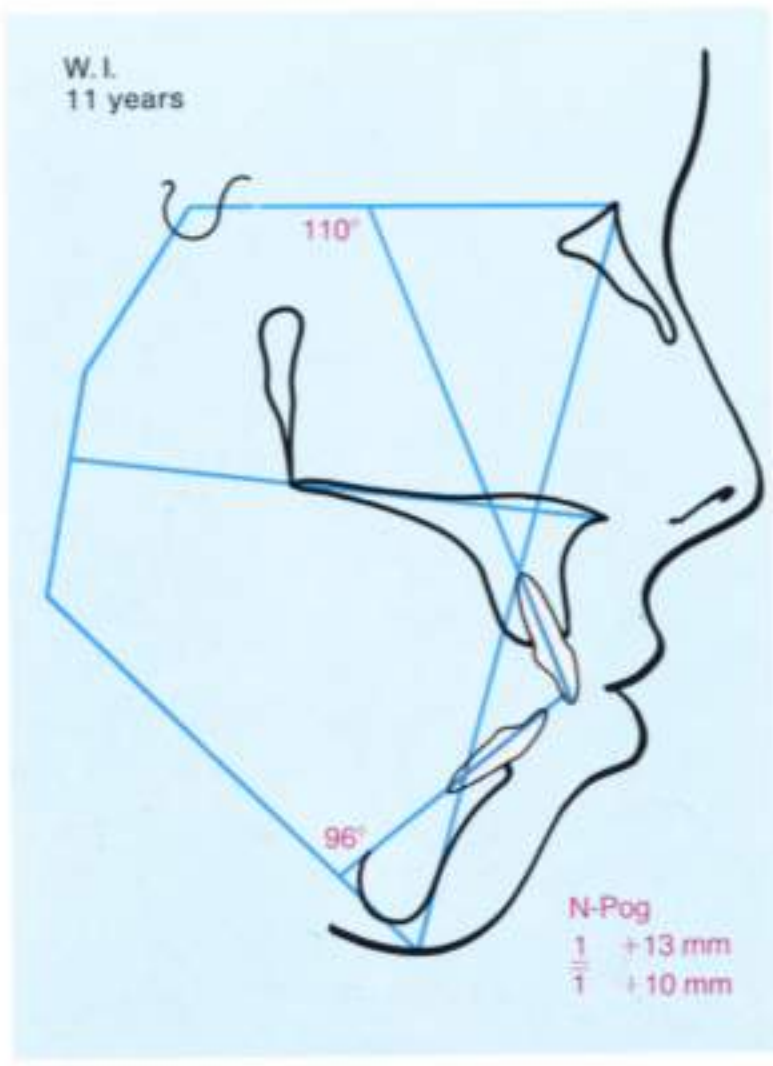


483 Bimaxillary dental protrusion

Left: Tracing of lateral cephalogram.

Upper and lower incisors are inclined labially. The distance of incisal edges to the N-Pog-line is markedly increased in both jaws.

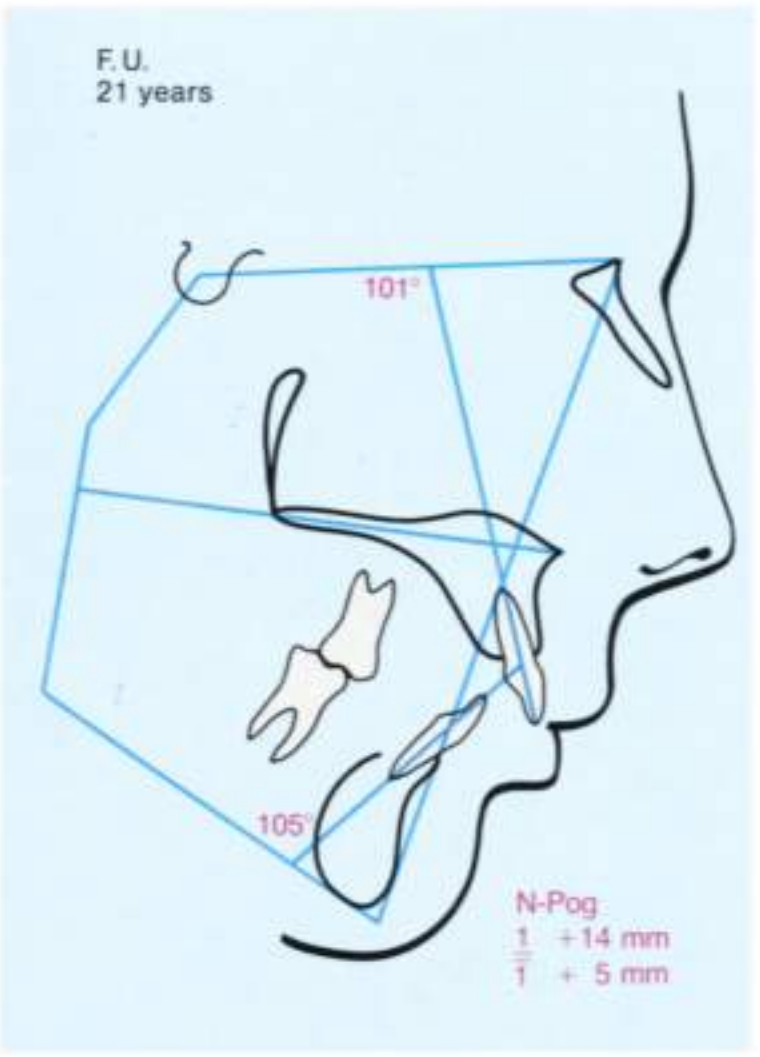
Right: Original lateral headfilm of the tracing.



Incisor inclination	Incisal edge to N-Pog-line	Therapeutic movement of anterior teeth
Labially inclined position	+ Anteposition	→ Tipping movement
Lingually inclined position	+ Retroposition	
Labially inclined position	+ Normposition	→ Root torque
Lingually inclined position	+ Anteposition	
Normal position	+ Anteposition	→ Bodily tooth movement
Normal position	+ Retroposition	

484 Analysis of incisor position and therapeutic consequences
Assessment of incisor axial inclination and distance of incisal edges to N-Pog-line determines the necessary tooth movements.

Depending on the combination of the malposition of the anterior teeth, correction requires either tipping – root torque – or bodily movement of the teeth.



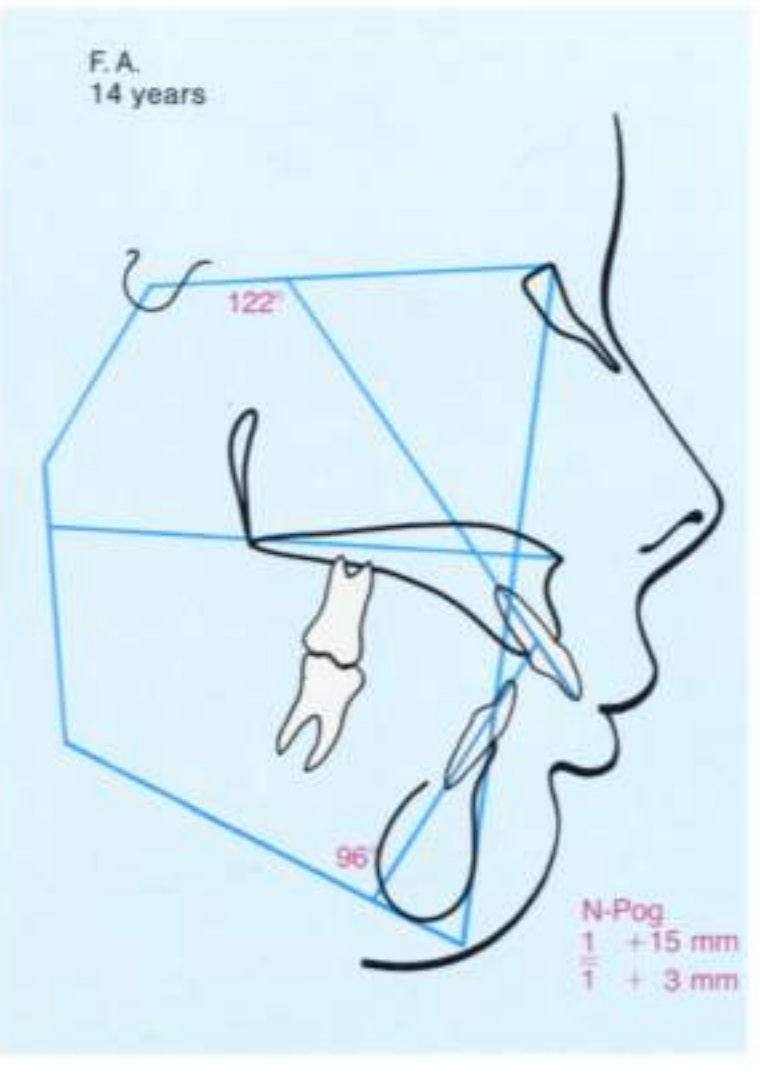
Class II malocclusions

485 Correct axial inclination of upper central incisor with anteposition to N-Pog-line
Left: The relevant measurements. Bodily tooth movement is required to correct the malposition of the upper anterior teeth.

To correct the position of the lower incisor, slight tipping and a labial root torque is necessary, i.e. the root is moved labially, with the center of rotation at the incisal edges.

Right: Original lateral cephalogram.

The N-Pog-line may still alter its relationship during the growth periods. With vertical rotation of the mandible, the distance of incisal edges to the reference line increases, but with horizontal growth pattern, it decreases.



486 Labioversion of the upper central incisor and anteposition to the N-Pog-line
Left: According to the angular and linear measurements, the labial inclination of the upper anterior teeth, can be realigned by tooth tipping as their incisal edges are in anteposition to the N-Pog-line.

To improve the position of the lower incisors, labial root torque is indicated in this case.

Right: Original cephalogram of the tracing.

Cephalometric Classification of Malocclusions

Class II Malocclusions

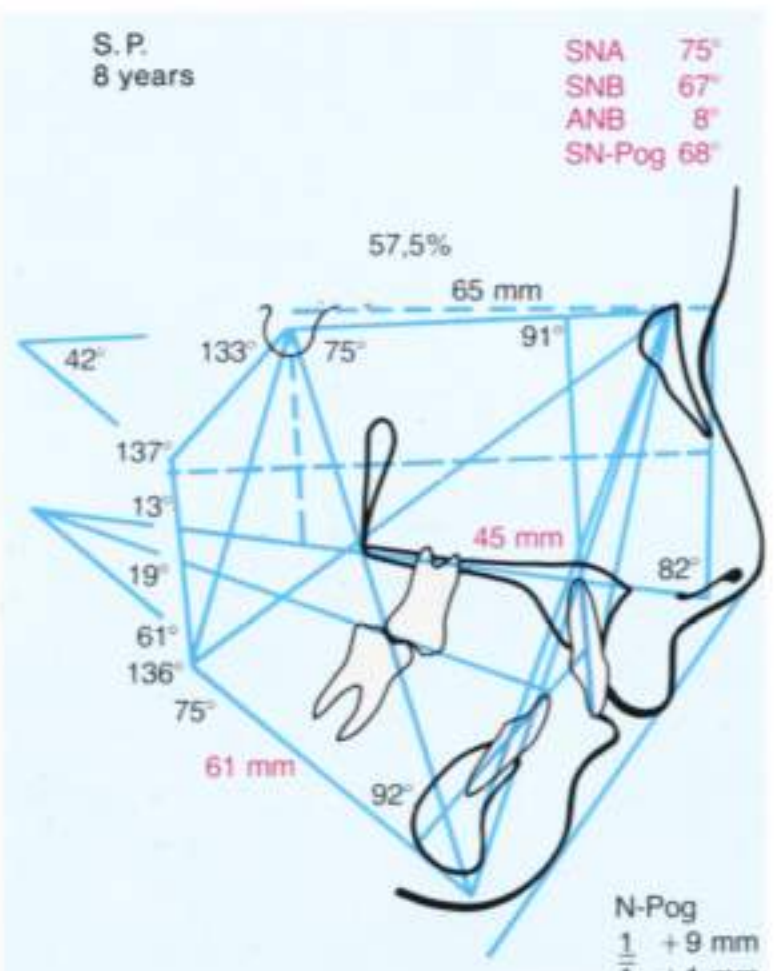
- Dentoalveolar Class II
- Anterior position of nasomaxillary complex
- Retrognathism of the mandible
- Neuromuscular Class II
- Combination types

487 Class II malocclusion with mandibular retrognathism

In this 8-year-old girl, the distoclusion is caused by the posterior position of the glenoid fossa (NSar angle 133°) and underdevelopment of the mandibular base.

The skeletal discrepancy is partly dentally compensated by the linguoversion of the upper incisors.

The prognosis for a causal therapy of this skeletal malocclusion is unfavorable because of the vertical growth pattern.

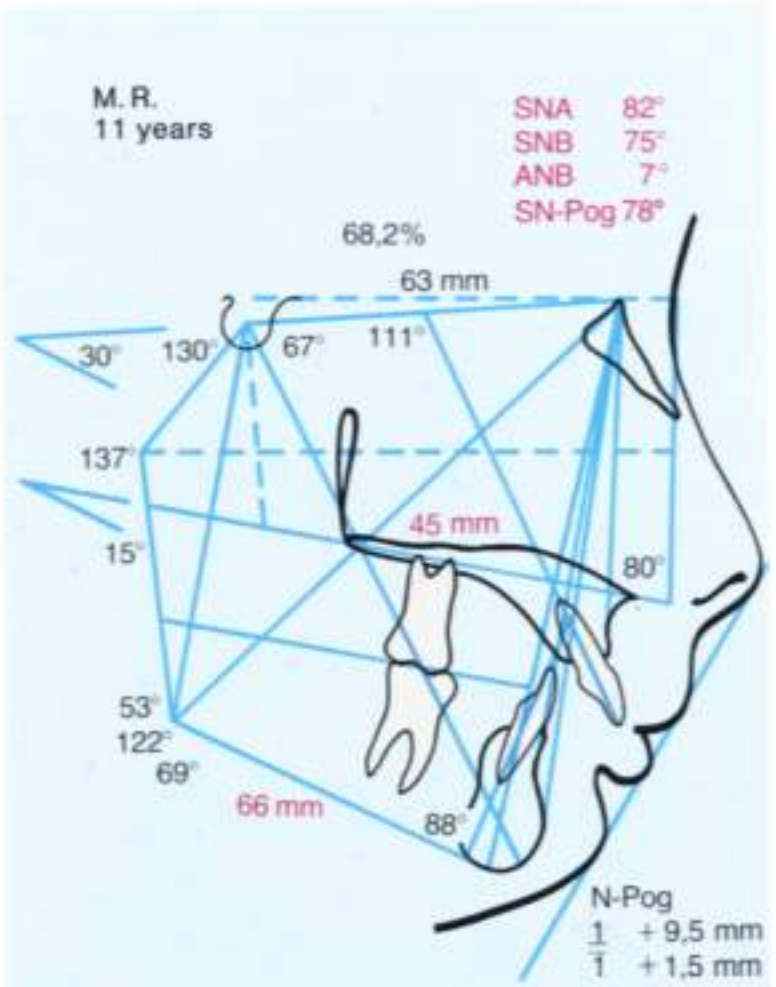


488 Class II malocclusion – Combination type

The *skeletal* causes of the anteroposterior jaw discrepancy are the anterior position of the maxillary base, as well as its overdevelopment in length, and the posterior position of the glenoid fossa (NSar angle 130°).

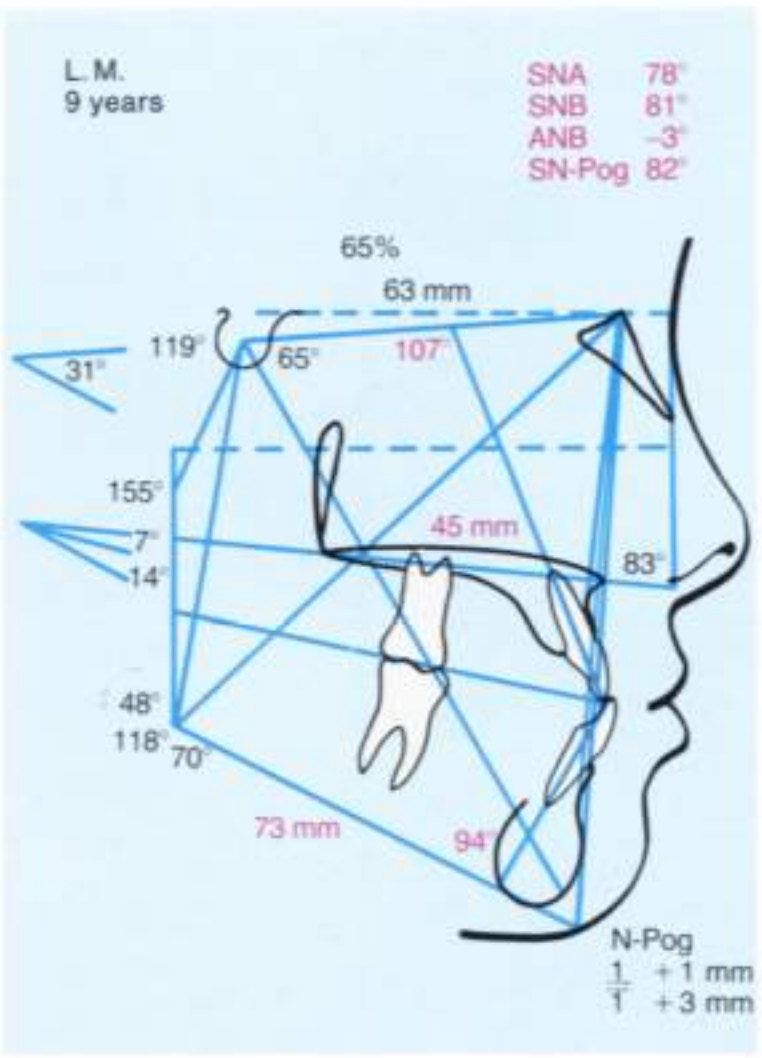
Dentoalveorly the malocclusion is enhanced by the labioversion of the upper anterior teeth.

The forward displacement of the mandible is inhibited by the anterior *neuromuscular imbalance*, with hyperactivity of the mentalis muscle.



Class III Malocclusions

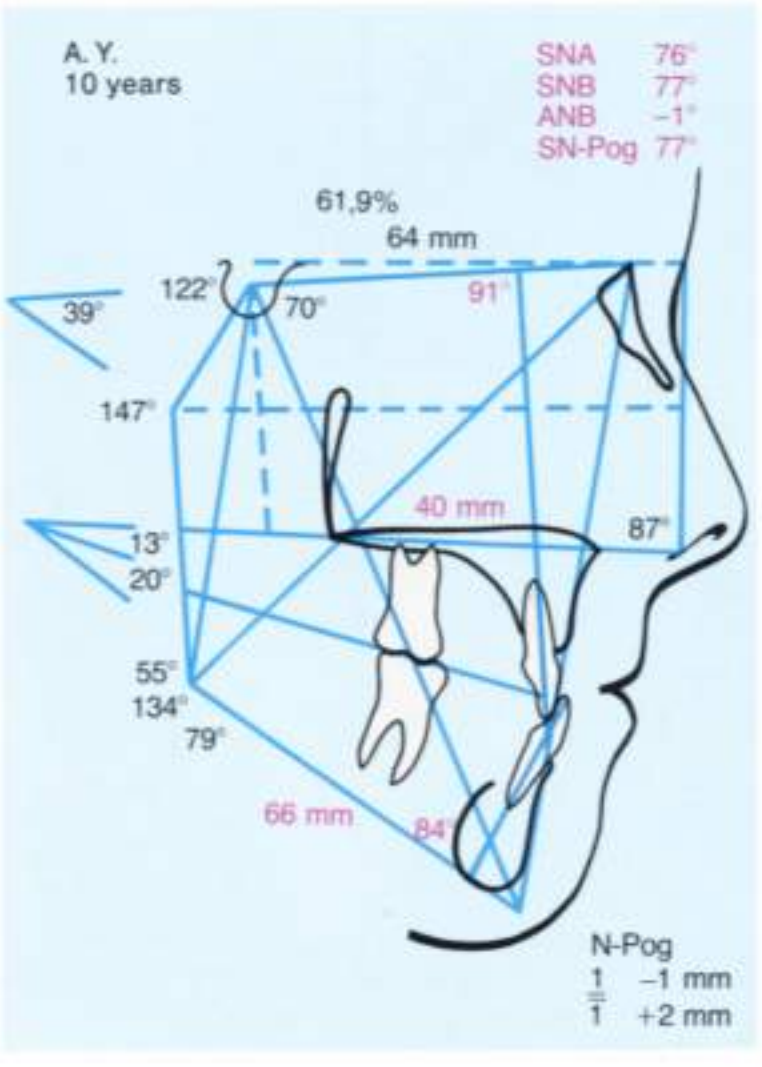
- Dentoalveolar Class III
- Overdevelopment of mandibular base
- Maxillary deficiency
- Combination types
- Pseudo-forced bite (dentoalveolar compensation of skeletal Class III)



489 Class III with overdevelopment of the mandible

Mandibular prognathism, with anterior position (NSar angle 119°) of an elongated mandibular body.

The length of the mandibular base is excessive by 7 mm, even before the start of maximum growth spurt.



490 Class III malocclusion with underdevelopment of the maxilla

Class III malocclusion with a short maxilla. Clinical appearance of the Class III is increased dentoalveolarly because of the relatively upright position of upper incisor teeth.

The prognosis of this dysgnathia is not favorable because of the vertical growth tendency of the mandible (facial height ratio = 61.9%).

Open bite

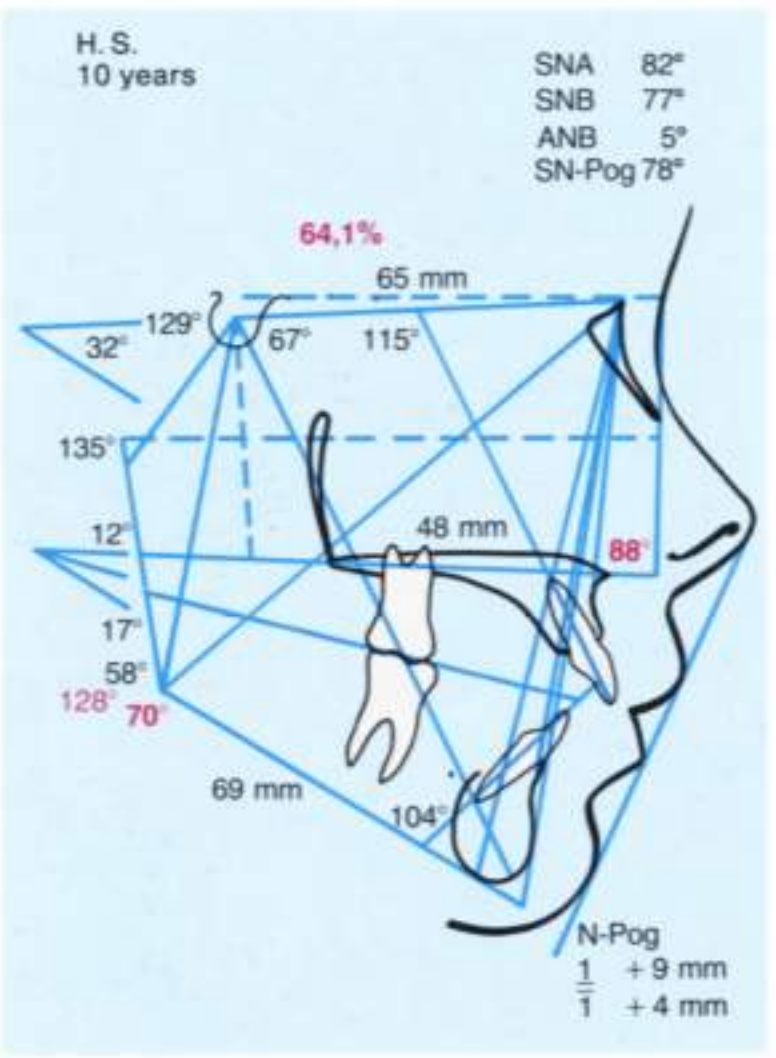
- *Dentoalveolar open bite*
  Infraposition of anterior teeth
  Supraposition of molars

- *Skeletal open bite*
  Vertical growth direction
  Anteinclination of maxillary base

491 Open bite – combination type

Class II malocclusion, with marked proclination of upper and lower incisor teeth, caused by long-standing sucking habit.

The causes of the anterior open bite are, *skeletally*, anteinclination of the maxilla and *dentoalveolarly*, the malposition of the anterior teeth. In this anomaly, the prognostic assessment for orthodontic treatment is favorable.



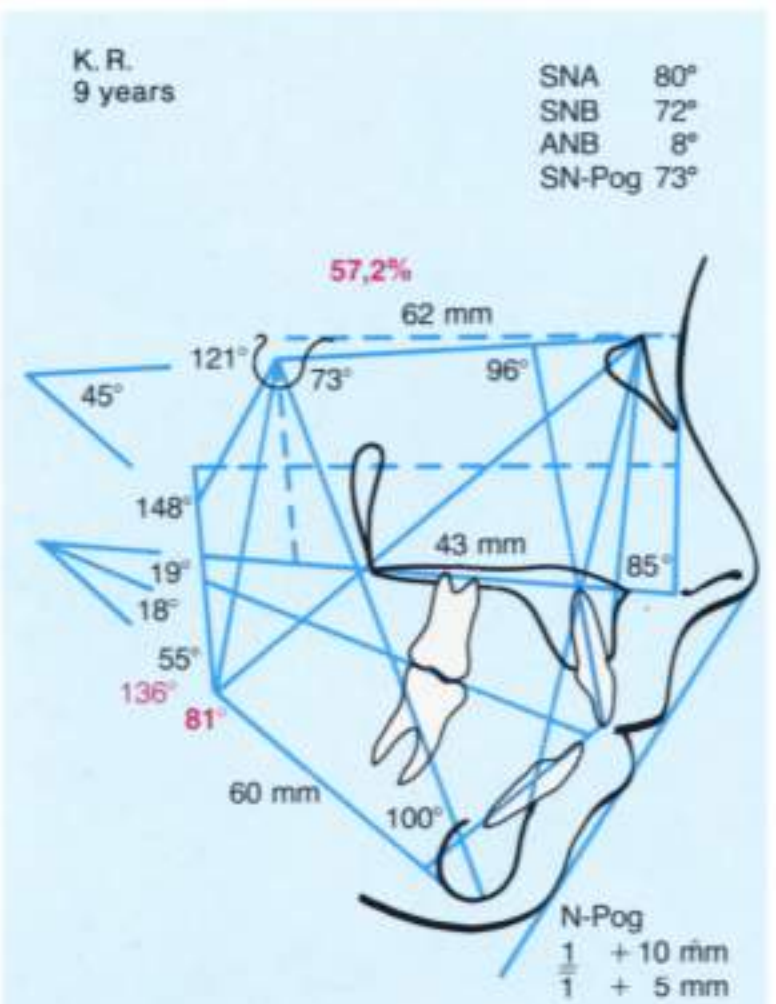
492 Skeletal open bite

Dysgnathia with a vertical growth pattern.

The downward and backward rotation of the mandible is the cause of the anterior open bite. The gonial angle and its lower segment are markedly enlarged.

The clinical picture of the open bite is partly compensated by the linguoversion of the upper anterior teeth.

As the age of maximum growth increments – the puberal spurt – has not yet been reached, an increase in the open bite can be expected.



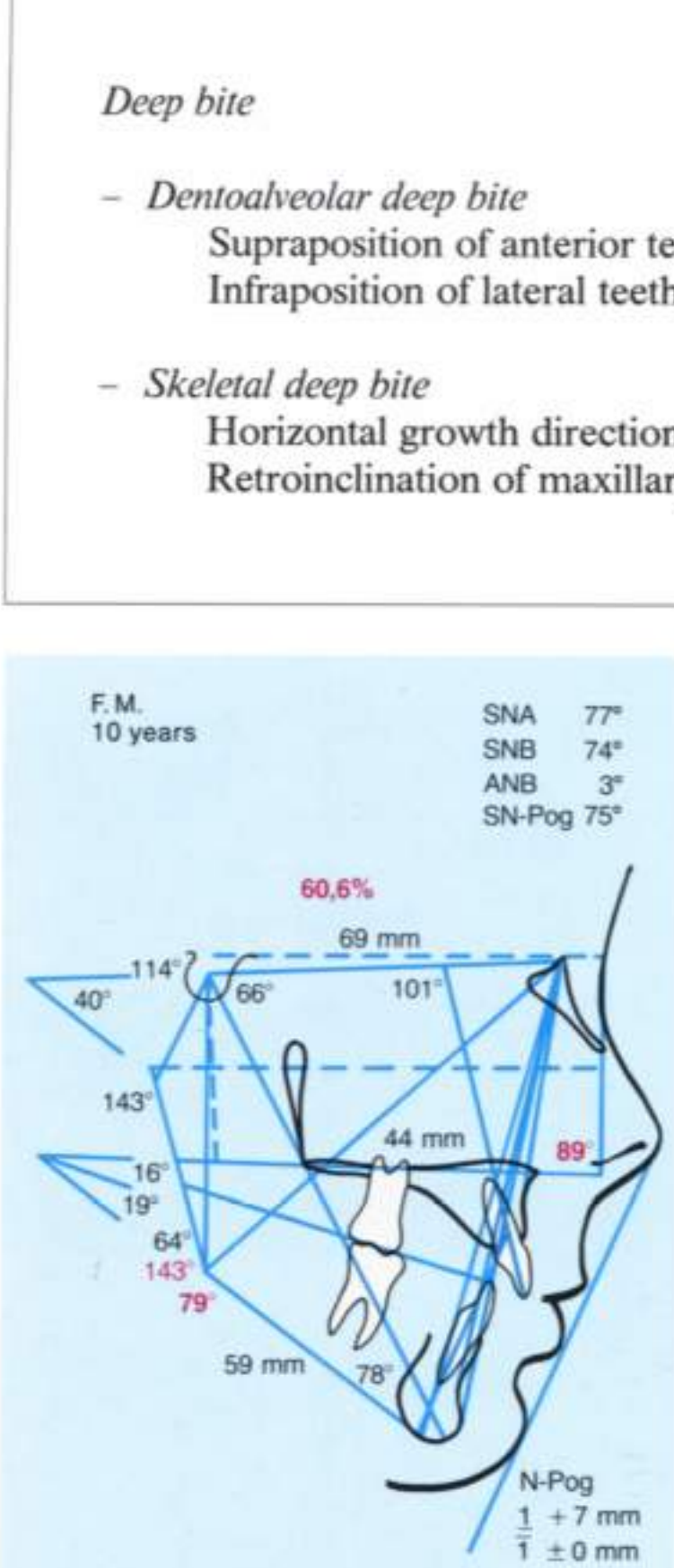
Deep bite

- *Dentoalveolar deep bite*
  Supraposition of anterior teeth
  Infraposition of lateral teeth

- *Skeletal deep bite*
  Horizontal growth direction
  Retroinclination of maxillary base

F. M.
10 years

SNA 77°
SNB 74°
ANB 3°
SN-Pog 75°



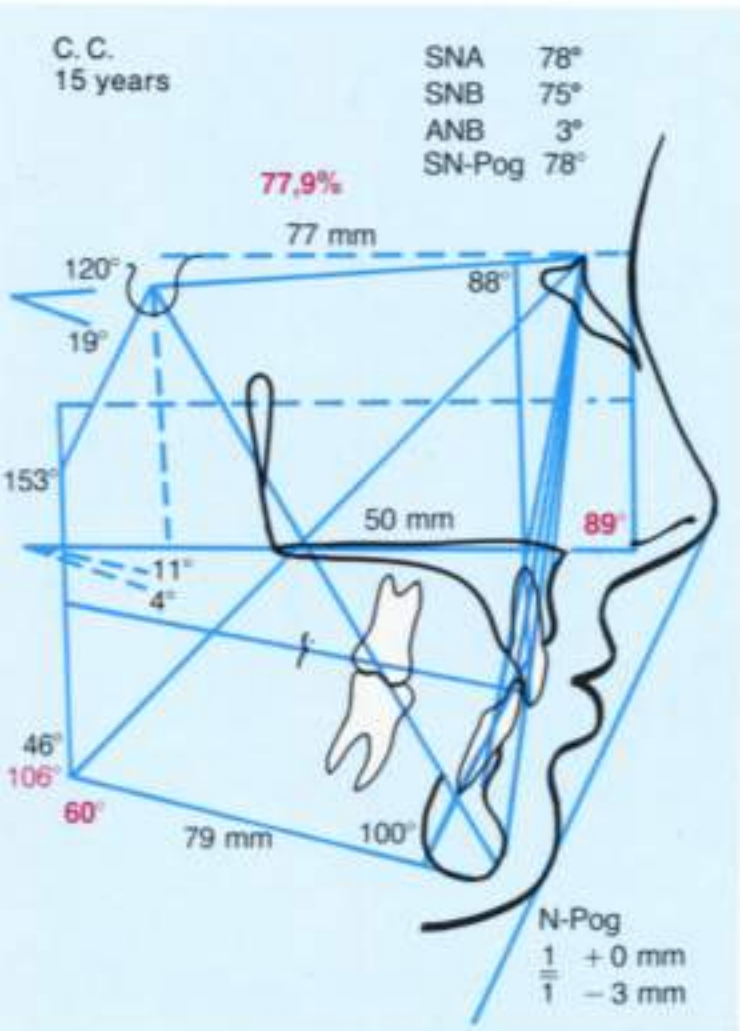
493 Dentoalveolar deep bite
Deep overbite in a case of vertical growth type, combined with anteinclination of the maxilla.

The etiology of the deep bite is dentoalveolar: supraposition of incisors with lingual tipping of the lower incisors and infraposition of first molars.

As downward and backward rotation of the mandible is to be expected, the prognosis for therapeutic bite opening is favorable.

C. C.
15 years

SNA 78°
SNB 75°
ANB 3°
SN-Pog 78°



494 Skeletal deep bite
The deep overbite is caused by the marked horizontal growth direction of the mandible, which is not compensated by the anteinclination of the maxilla.

Dentoalveolarly, the skeletal dysplasia is increased by the linguoversion of the upper anterior teeth.

Cephalometric Radiography – Prognostic Assessment

Cephalometric radiography provides important information for the prognostic assessment of the malocclusion. For example; Class II anomalies with a horizontal growth pattern have a good prognosis for changing the anteroposterior jaw relationships; however, the prognosis is bad for bite opening.

The opposite to this is the unreliable treatment prognosis for anterior displacement of the mandible in a Class II malocclusion with vertical growth tendency. The prognosis regarding correction of a deep bite is favorable.

The prognostic assessment of sagittal and vertical dysgnathias is determined by the growth direction:

Malocclusion	Favorable Prognosis	Unfavorable Prognosis
Class II with horizontal growth pattern	→ Change of sagittal jaw relationships	→ Bite opening
Class II with vertical growth pattern	→ Bite opening	→ Change of sagittal jaw relationships
Class III with horizontal growth pattern	→ Change of sagittal jaw relationships	→ Bite opening (if necessary)
Class III with vertical growth pattern	→ Not favorable	→ Bite closing
Deep bite Open bite	→ Dentoalveolar malocclusion	→ Skeletal malocclusion

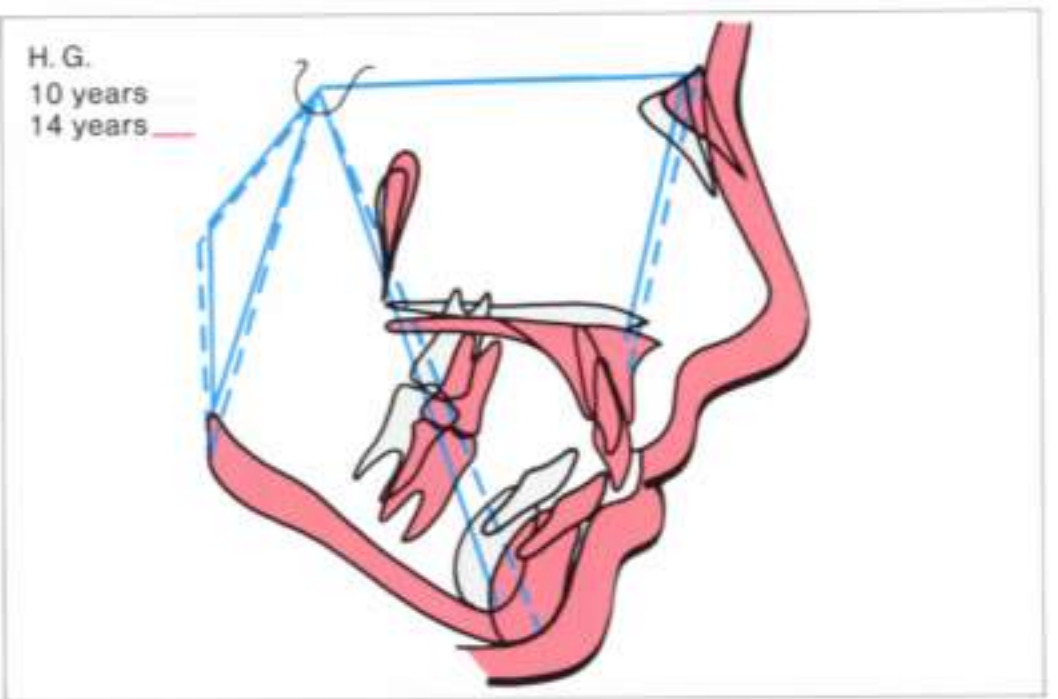
Cephalometric follow-up

Gray = Pretreatment tracing
Red = Posttreatment tracing

495 Class II malocclusion with a horizontal growth pattern

During 4 years of observation the retruded position of the mandible has been self-corrected by forward growth of the mandible.

Changes are the result of marked increase in length of the mandibular base and the physiologic upward and forward displacement of the mandible.



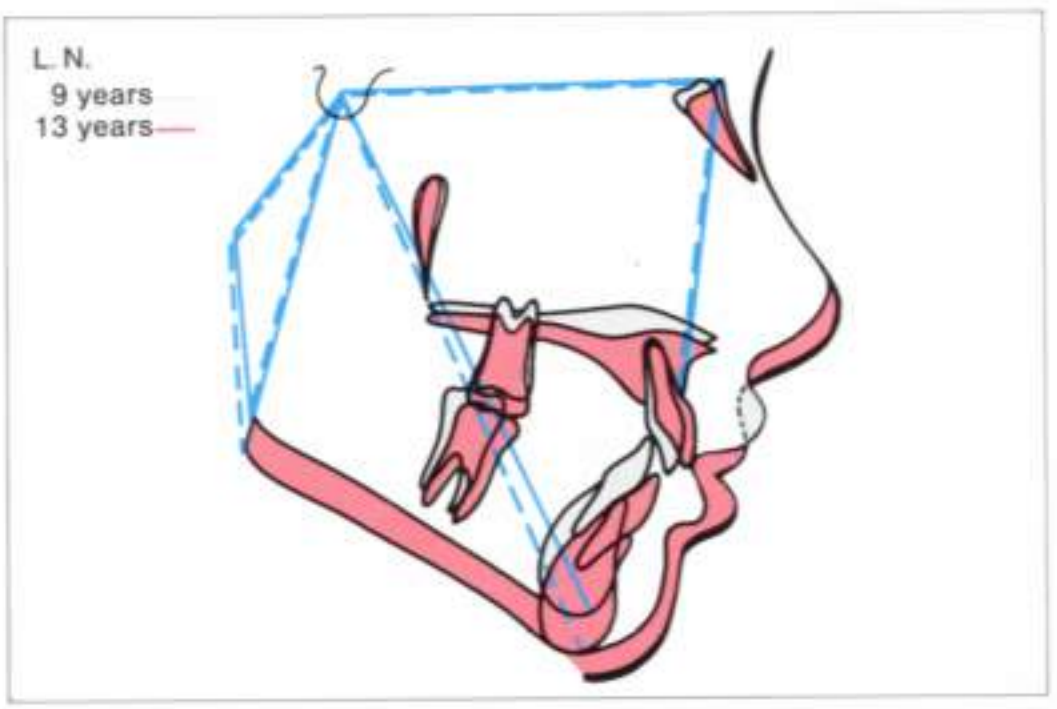
496 Class II malocclusion with vertical growth pattern

The initial findings show a Class II relationship with a dentally supported overbite.

The anteroposterior jaw discrepancy persists at the end of the 3-year observation period, which means that spontaneous balancing due to growth did not occur.

It is characteristic for the vertical growth type that there is downward and backward rotation of the mandible.

An anterior open bite is present at the end as the result of mandibular rotation.



Record Sheet
Radiographic Cephalometric Analysis (Lateral Radiograph)

Patient:		Date of Birth:	Sex:		
	Clinical Standard value	Actual value (Date)		Clinical Standard value	Actual val. (Date)
NSar (saddle angle)	123° ± 5°		1-SN	102° ± 2°	
SarGo (articular angle)	143° ± 6°		1-SpP (acc. to *Schwarz*)	70° ± 5°	
GoMe (gonial angle)	130° ± 7°		$\overline{1}$-MeGo	90° ± 3°	
Sum of posterior angles Horizontal growth Vertical growth	394°		N-Pog to 1	+2 – +4 mm	
			N-Pog to $\overline{1}$	–2 – +2 mm	
Go_1 (NGoar angle)	52°–55°		Interincisal angle	135°	
Go_2 (NGoMe angle)	70°–75°		S-ar	35 mm	
SNA	81°		$\overline{NSe}$ (+3 mm = ideal mandibular length)	mm	
SNB	79°				
ANB	2°				
SN-Pog	80°				
Pal-GoMe (basal angle)	25°				
Pal-OcP	11°				
MeGo-OcP	14°				
SN-MeGo	34°				
SeN-Pal (Incl. angle)	85°				
NS-Gn (Y-axis)	66°				
SGo: NMe × 100	62–65%				

	Mandible	Maxilla	Ramus length	Ramus width
Ideal value				
Actual value				

Symphysis: normal – thin – thick		
Distance to esthetic line Lab. sup.	–1 – –4 mm	
Lab. inf.	0 – +2 mm	
Other findings:		

Findings

Facial Skeleton

a) Vertical
Rotation of the mandible: neutral – horizontal – vertical
Rotation of the maxilla: normal – anteinclination – retroinclination
Rotation of jaw bases: divergent – convergent – same direction upward/downward

b) Sagittal
Maxilla: orthognathic – retrognathic – prognathic
Mandible: orthognathic – retrognathic – prognathic
Jaw base relationship: Class I – Class II – Class III

Measurement of Jaw Bases
Maxilla: normal – decreased – increased
Mandible: normal – decreased – increased

Dental analysis
Maxillary incisors:
Axial inclination: correct – labial – lingual
Relation to N-Pog: normal – anterior – posterior

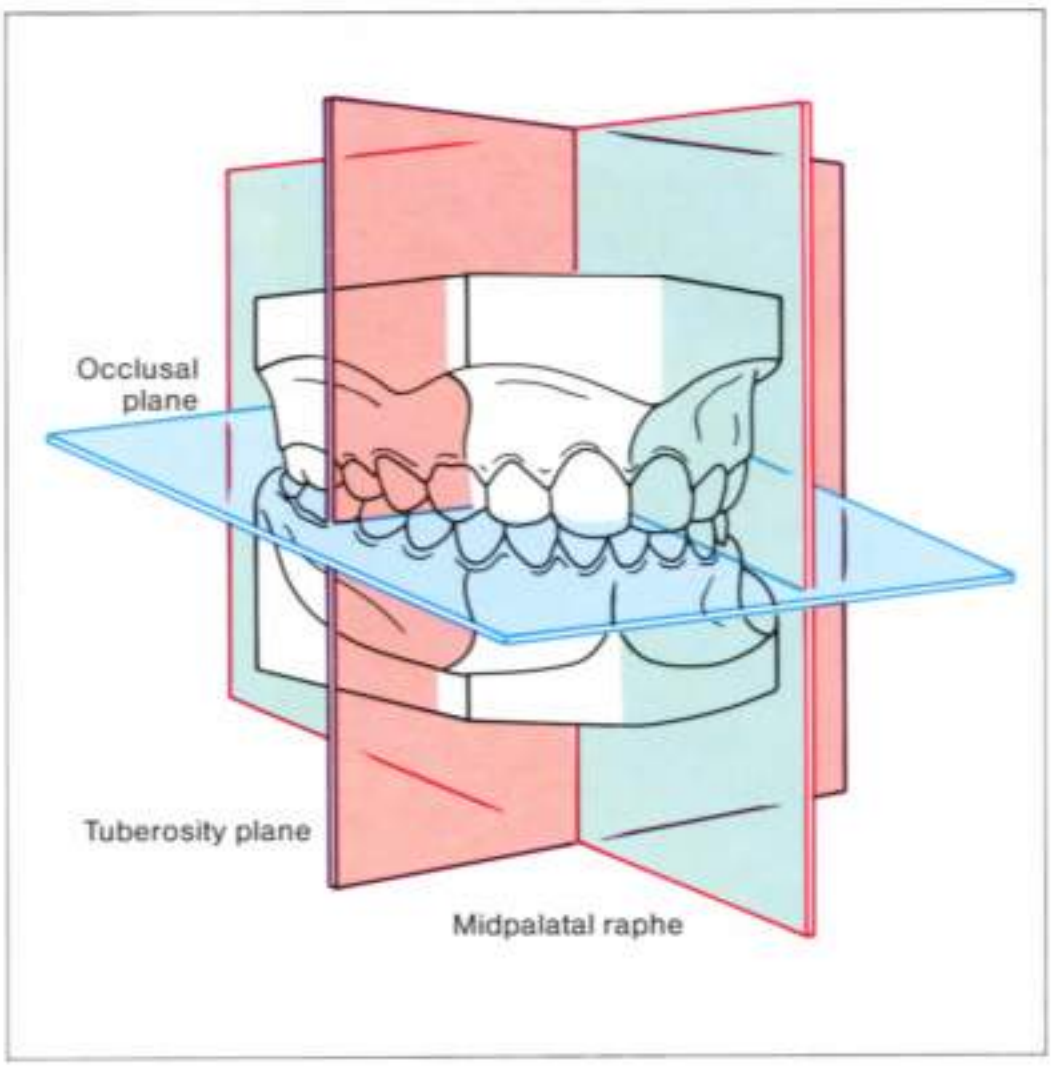
Mandibular incisors:
Axial inclination: correct – labial – lingual
Relation to N-Pog: normal – anterior – posterior

Study Cast Analysis

Study cast analysis is a three-dimensional assessment of the maxillary and mandibular dental arches and the occlusal relationships.

The importance of this method of evaluation for orthodontic diagnosis and treatment planning has in the past been over-emphasized. The *disadvantage* of odontometrics lies in the fact that it concerns correlation analyses, which in dependence on tooth size asses the width and length of the dental arches arithmetically. Too often, model analysis is not correlated with other important diagnostic criteria, i.e. cephalograms and panoramic radiographs. A certain correlation between arch length, width, and mesiodistal tooth material does exist, however. These relationships are defined as *indices* by various authors. The indices of Pont, Linder, Harth, and Korkhaus are the most commonly used in German-speaking countries. In these cast analyses, the actual value of the individual case is compared with the standard values of the "normal arch". With present-day knowledge, this method is often considered to have minimal diagnostic value. Nevertheless, this procedure is still widely used in orthodontic practice.

Despite these limitations, a great *advantage* of study cast analysis is that the degree of malocclusions can be diagnosed in three dimensions. The plaster models for study cast analysis are oriented to the following *planes:* 1) midpalatal raphe (midsagittal plane), 2) tuberosity plane, and 3) the occlusal plane (Fig. 497).



497 Orientation of study cast models

For the necessary examination, the plaster models are oriented with respect to three reference planes, which lie at right angles to one another.

Midpalatal raphe plane = midsagittal plane, which is defined by anatomical points on the palatine raphe (see Figs. 511, 512). It is the reference plane for assessment of transverse discrepancies.

Tuberosity plane = parafrontal plane which runs through the maxillary tuberosities respectively through the distal-most tuberosity. It is the reference plane for analysis of anteroposterior dental malpositions

Occlusal plane = horizontal plane through the tips of the buccal cusps of the premolars or the tips of the mesiobuccal cusps of the first molars and first premolars. This plane allows vertical malpositions to be assessed.

Metric Analysis of Arch Form

- Sum of upper incisors (SI_u)
- Anterior arch width
- Posterior arch width
- Anterior arch length
- Palatal height

Dental Arch Width

The standard values (often referred to as "normal values") of the transverse arch width in the premolar and molar region depend on the mesiodistal size of the four upper incisors (SI_u) (Pont, Linder, Harth). Since the dental reference points for maxillary and mandibular anterior and posterior arch width lie exactly opposite each other in the anatomically correct occlusion, the ideal values are equal for both jaws.

Comparing the ideal value with the actual value, the following deviations from the norm may occur: narrowness and broadness of dental arches.

The correlation analysis is inaccurate if the SI_u is very large or very small, and is influenced by morphologic variabilities of the upper incisors. In these cases the SI_u has to be calculated with the help of the Tonn Formula, using the sum of the lower incisor width.

In principle, the so-called Pont relation discrepancies are only to be taken into account if larger differences are present and should not be interpreted in isolation but only together with other findings. These measurements are a guide, not a goal.

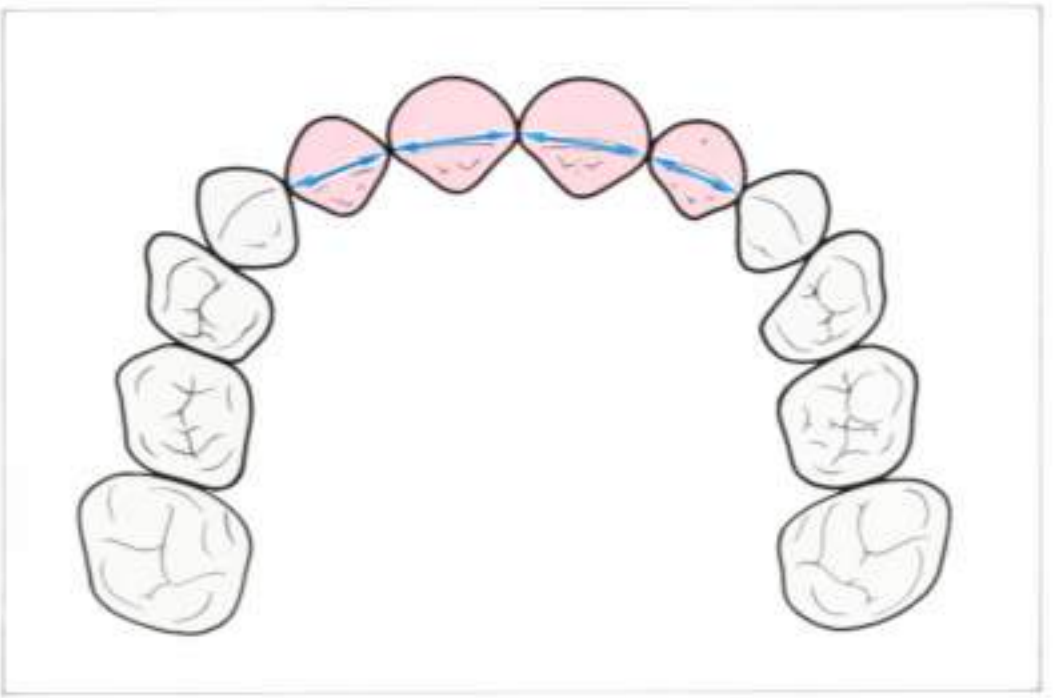
Sum of the incisors

498 Sum of upper incisors (SI_u)

Starting-point for incisor width/arch width index according to Pont is to determine the SI_u.

The maximal mesiodistal width of each maxillary incisor is measured and the single values are added together.

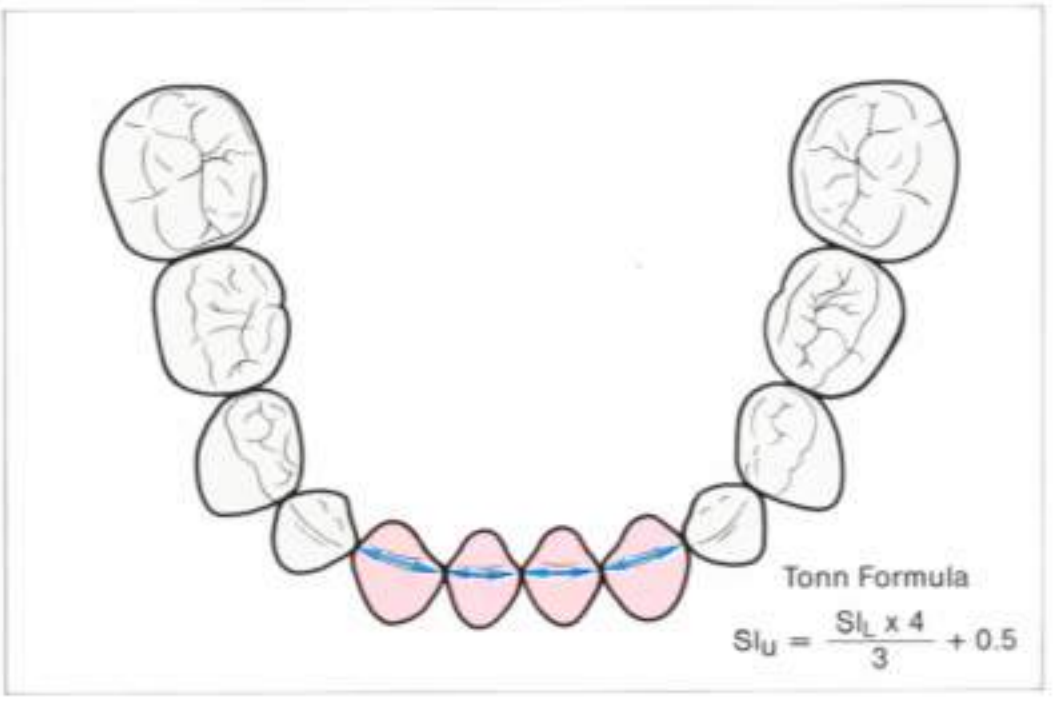
Right: The measurements can be carried out on the model or – for greater precision – directly in the mouth during clinical examination.

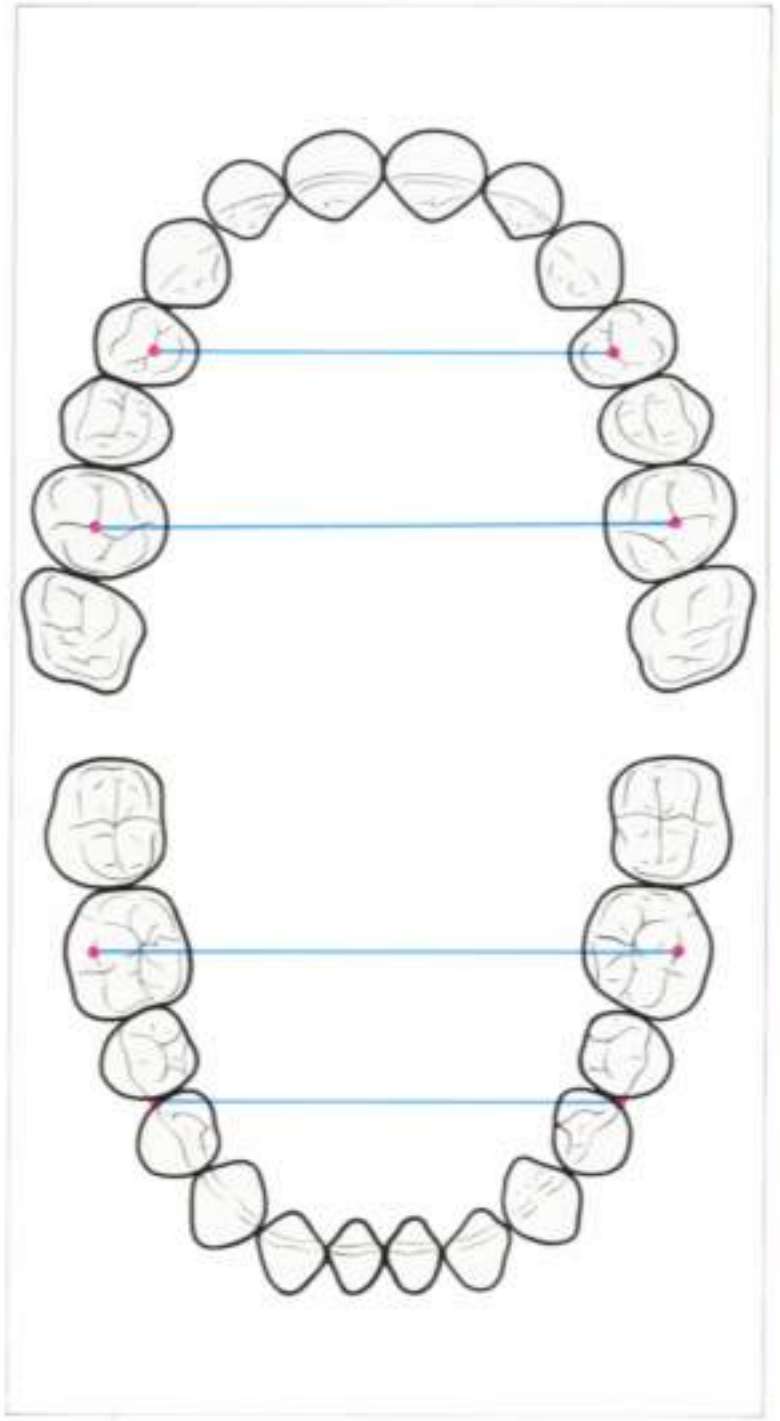


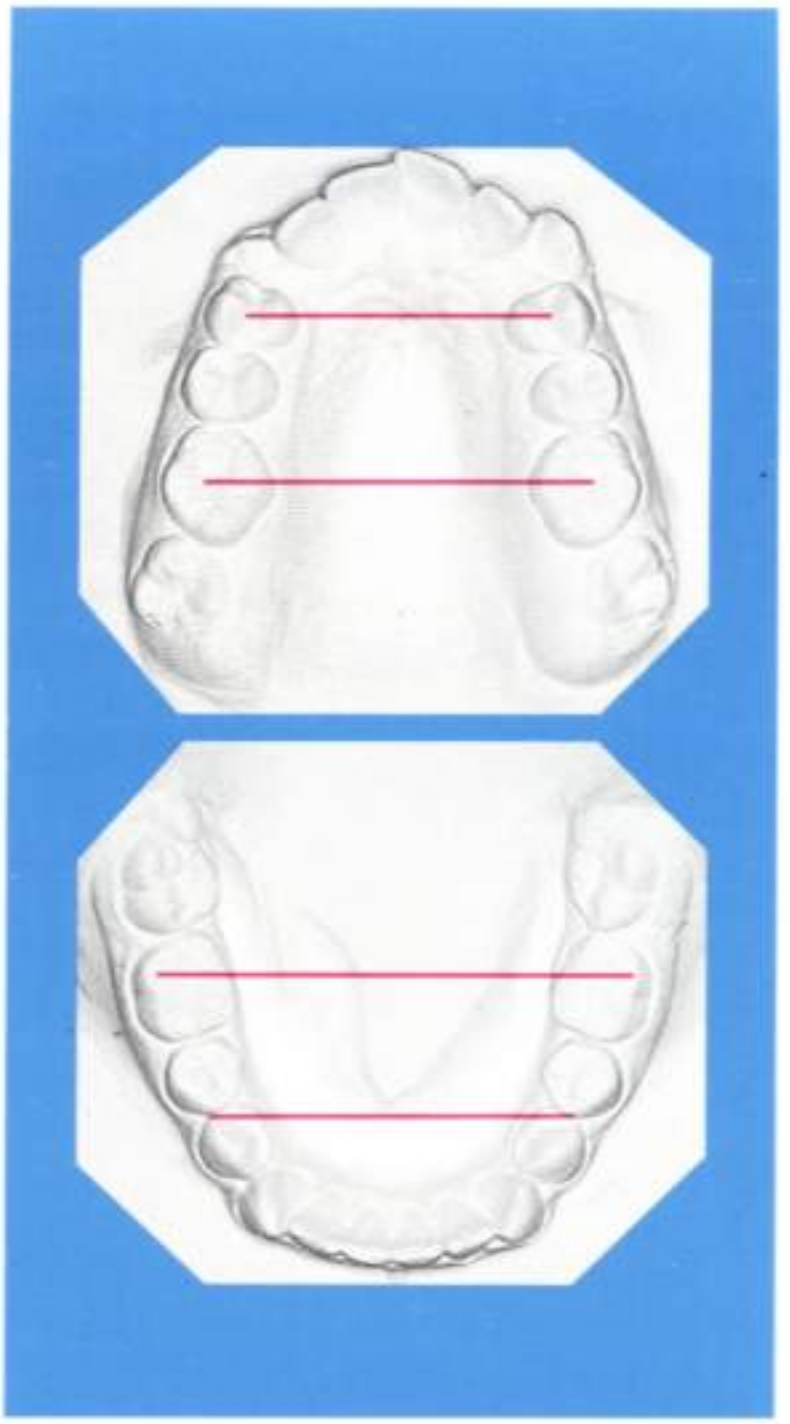
499 Sum of lower incisors (SI_L)

If upper central or lateral incisors are missing, determinations may be made based on the sum of the lower incisor width, using the Tonn Formula of all four upper incisors which calculates the appropriate width.

Right: In cases of hypo- or hyperplasia of maxillary incisors, the SI_u must be calculated by the Tonn Formula when using the Pont-Index.







Anterior and posterior arch width

500 Measurements of dental arch width after eruption of the first premolars

The reference points for measurements in the maxillary and mandibular arch are defined so that in an anatomically correct occlusion, the upper and lower points are directly opposed.

Definition of reference points:

Maxilla anterior = lower-most point of the transverse fissure of the first premolar.

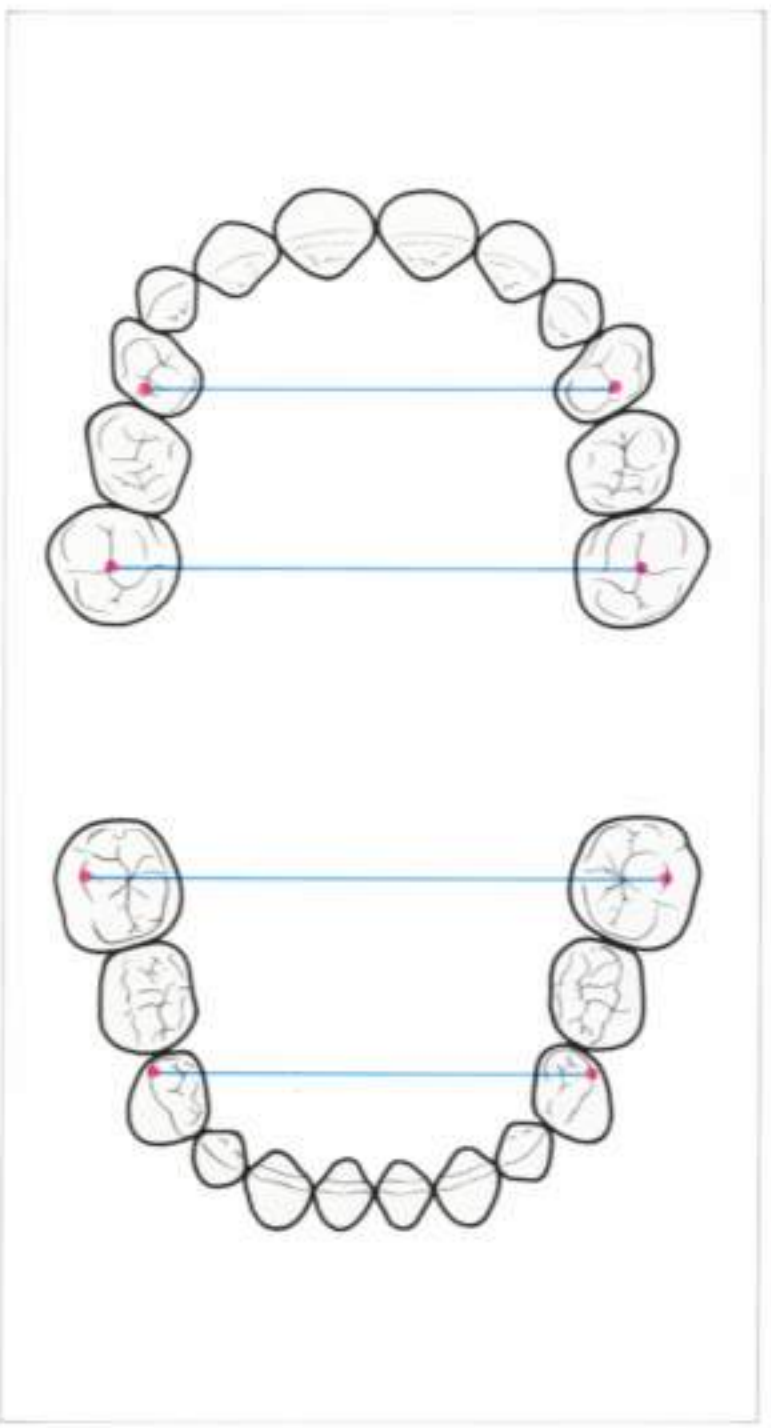
Maxilla posterior = point of intersection of the transverse fissure with the buccal fissure of the first permanent molar.

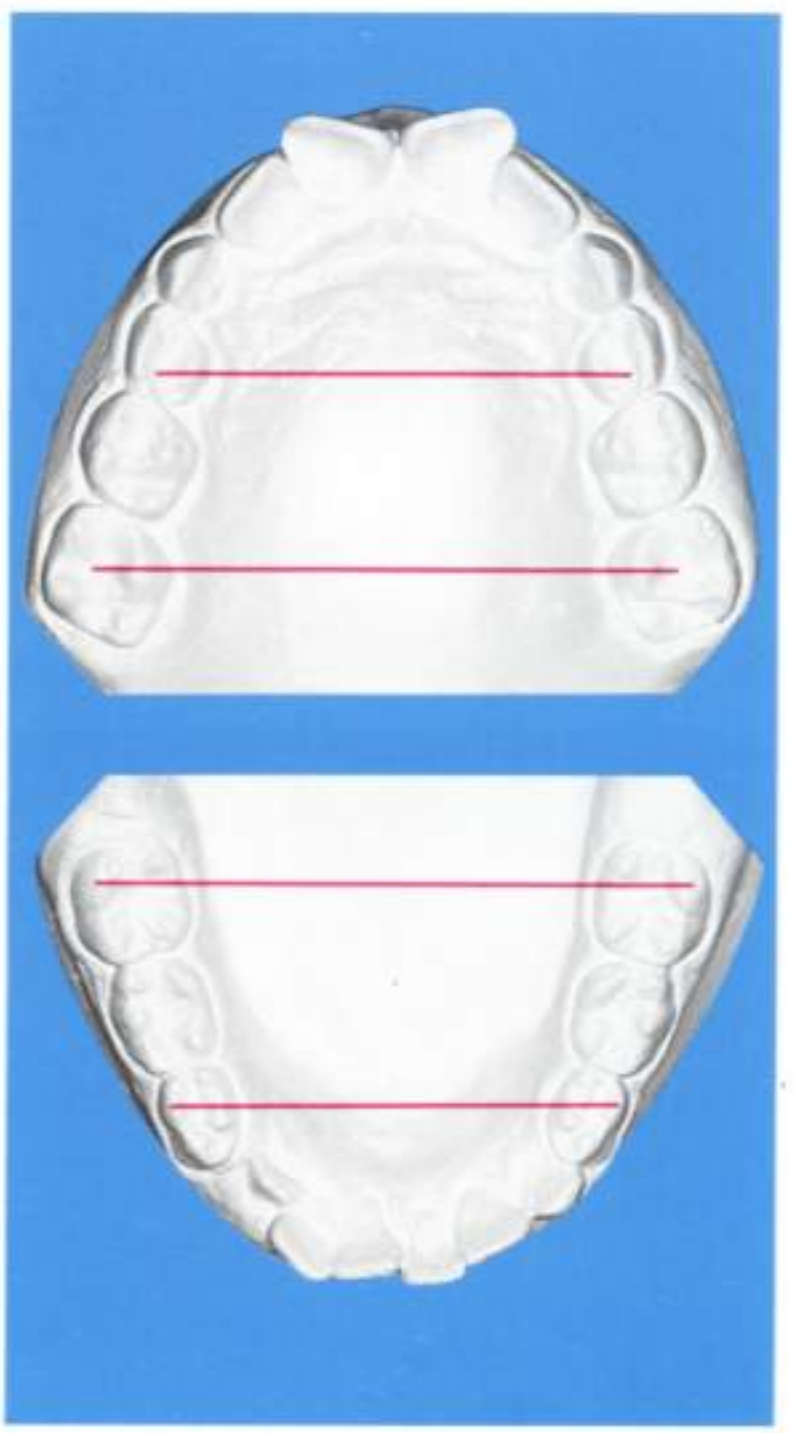
Mandible anterior = facial contact point between first and second premolars.

Mandible posterior = tip of the mediobuccal cusp of the lower first permanent molar.

The anterior arch width is defined as the distance between the anterior reference points (premolar region). The posterior width is the distance between the first molars.

The "ideal" values of anterior and posterior arch width are determined by using the Pont index.





501 Measurement of dental arch width in the early mixed dentition

The anterior arch width is measured in the region of the first deciduous molars when primary teeth are still present in the supporting zones.

Definition of reference points:

Maxilla: posterior groove of the transverse fissure of the first deciduous molar.

Mandible: distobuccal cusp tip of first deciduous molar.

The posterior arch width is measured exclusively in the region of the 6-year-molars.

502 Correlation table between the sum of upper incisors and dental arch width

Table of mean values for arch width assessment according to different investigators (*Weise* and *Benthake*, 1965). Since the maxillary and mandibular reference points correspond, the standard values are valid (mm) for both jaws.

The formula for the Pont-Index according to *Linder* and *Harth:*

Ideal value anterior arch width

$$= \frac{SI_u \times 100}{85}$$

Ideal value posterior arch width

$$= \frac{SI_u \times 100}{65}$$

The deviation in the transverse development of the arch width is represented by the difference between the actual and the standard (so-called normal) values.

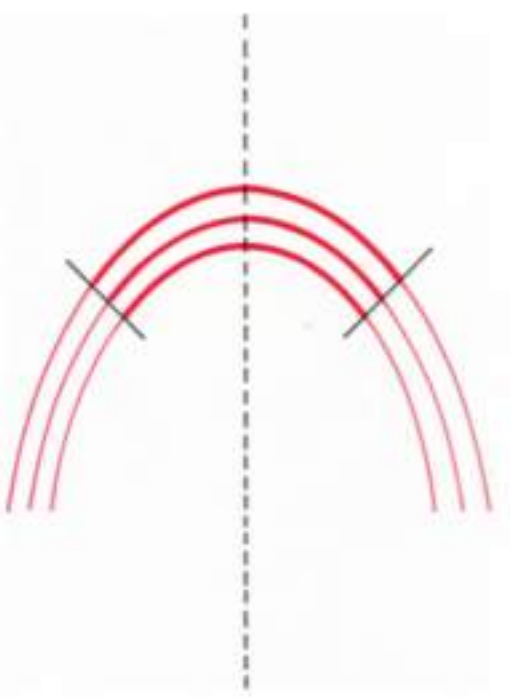
SI_u (mm)	Anterior arch width					Posterior arch width				
	Pont	Harth	Schmuth	Ritter	Weise	Pont	Harth	Schmuth	Ritter	Weise
27	33.5	32	35		34.8	42.5	41.5	43		47.1
27.5		32.5			35.2		42.3			47.5
28	35	33	36	36	35.5	44	43	44	48	47.8
28.5		33.5			35.8		43.8			48.2
29	36	34	37	36.5	36.2	45.3	44.5	45	48.5	48.6
29.5		34.7			36.5		45.3			48.9
30	37.5	35.5	38	37	36.8	46.9	46	46	49	49.3
30.5		36			37.2		46.8			49.7
31	39	36.5	39	37.5	37.5	48.2	47.5	47	49.5	50.1
31.5		37			37.8		48.5			50.4
32	40	37.5	40	38	38.2	50	49	48	50	50.8
32.5		38.2			38.5		50			51.1
33	41	39	41	38.5	38.8	51.5	51	49	50.5	51.5
33.5		39.5			39.2		51.5			51.8
34	43	40	42	39	39.5	53	52.5	50	51	52.2
34.5		40.5			39.8		53			52.6
35	44	41.2	43	39.5	40.2	54.5	54	51	51.5	53.0
35.5		42			40.5		54.5			53.3
36	45	42.5	44	40	40.8	56.3	55.5	52	52	53.7

503 Correlation between dental arch form and sum of incisors

The Pont-Index is based on various examinations of the geometry of normal dental arches.

According to these graphic diagrams, the size of the near-elliptical shape of the maxillary dental arch is related to the width of the upper incisor teeth.

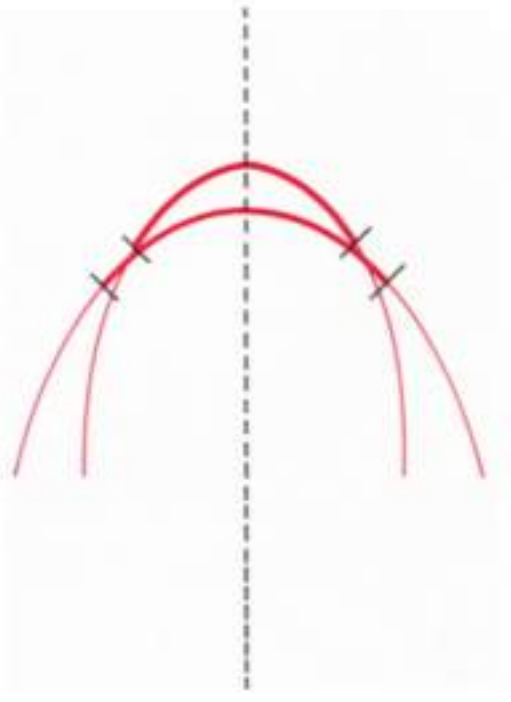
Right: Depending on the sum value of the upper incisors, the elliptical forms are of different size but of similar shape (*Korkhaus* 1939).



504 Correlation between dental arch width and arch length

View of a wide, short maxillary arch. The shape of the normal arch depends on the development of width and length, which is in the ratio of 2:1. For example, if the arch width is increased by 2 mm, the arch length is reduced by 1 mm.

The ideal arch width value determined according to Pont can be individualized if both parameters (length and width) are considered.

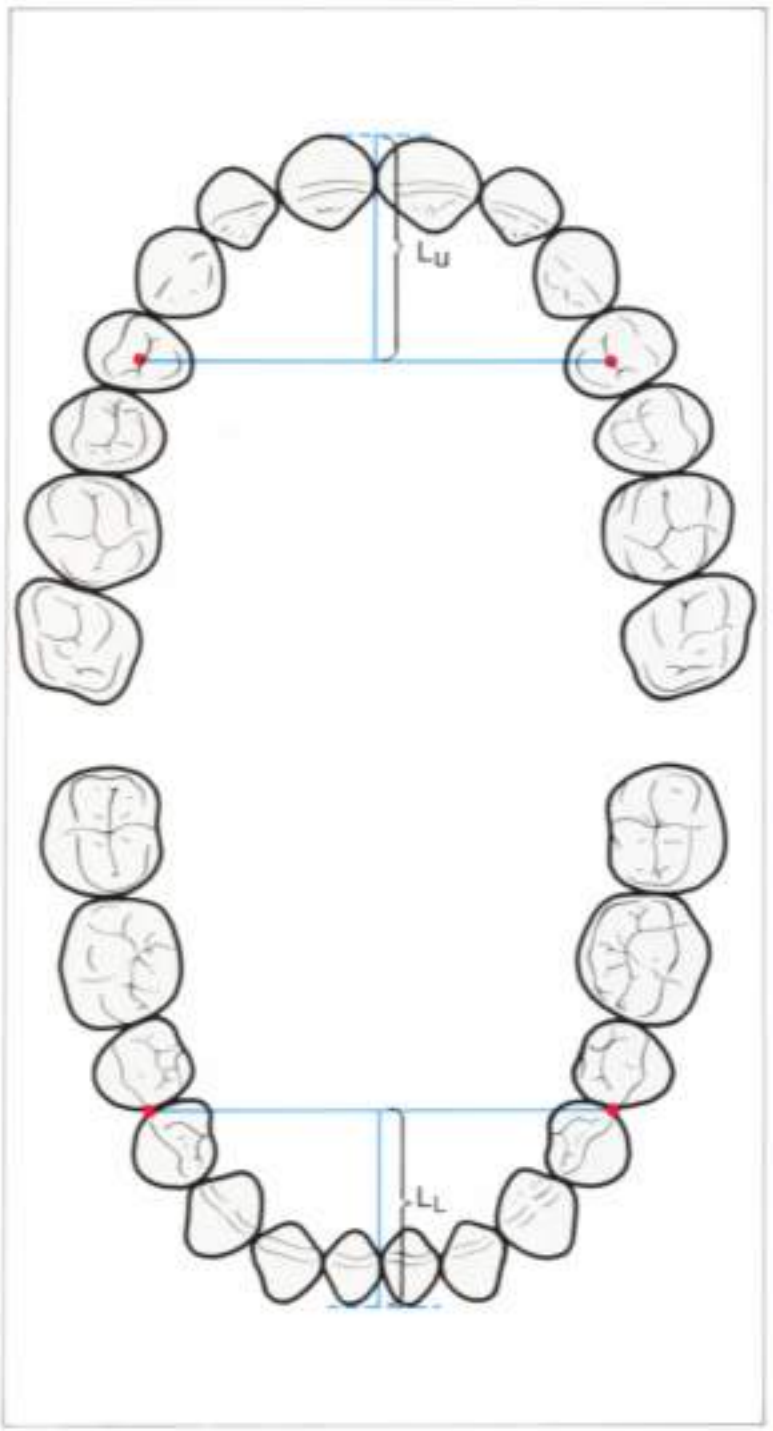


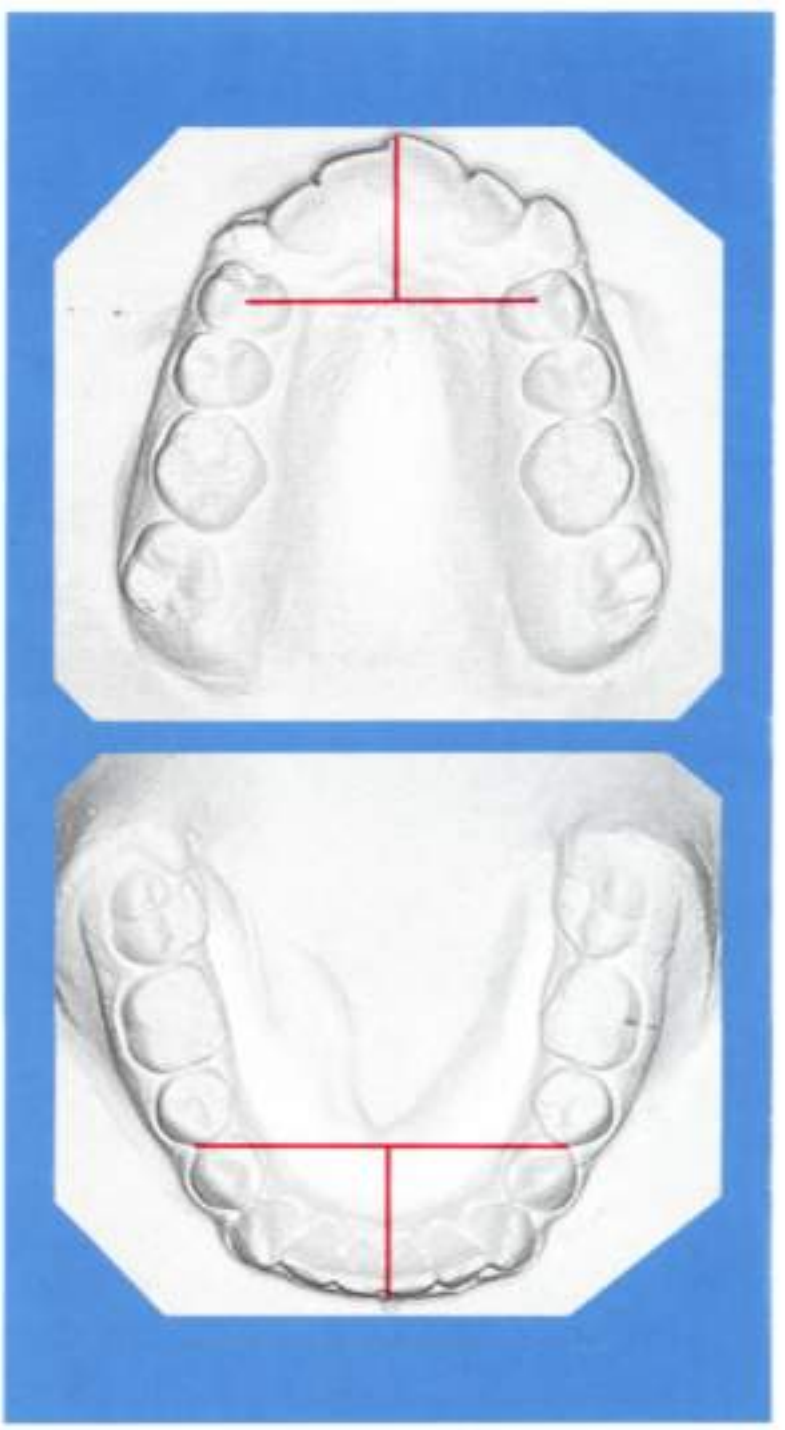
Anterior Dental Arch Length

The anterior arch length according to Korkhaus (L_u in the maxilla, L_L in the mandible) is defined as the perpendicular from the most anterior labial surface of the central incisors to the connecting line of the reference points of the anterior arch width (p. 209). The measurement should reveal the *anteroposterior malpositioning of the anterior teeth.*

As with the Pont-Index, the standard values of the anterior arch length are statistically correlated, dependent on the sum of mesiodistal tooth width of the upper incisors (SI_u). The anteroposterior length of the anterior mandible is normally 2 mm shorter than the maxillary arch (labiolingual diameter of the incisal edges of the upper incisors). Certain diagnostic and prognostic indications regarding an anteroposterior displacement of the incisors can be gained by comparison of the standard and actual values.

The anterior arch length is, however, not only altered by malpositioning of the anterior teeth, but also by migration of the first premolars. The correlation between arch length and arch width varies considerably with different facial types.

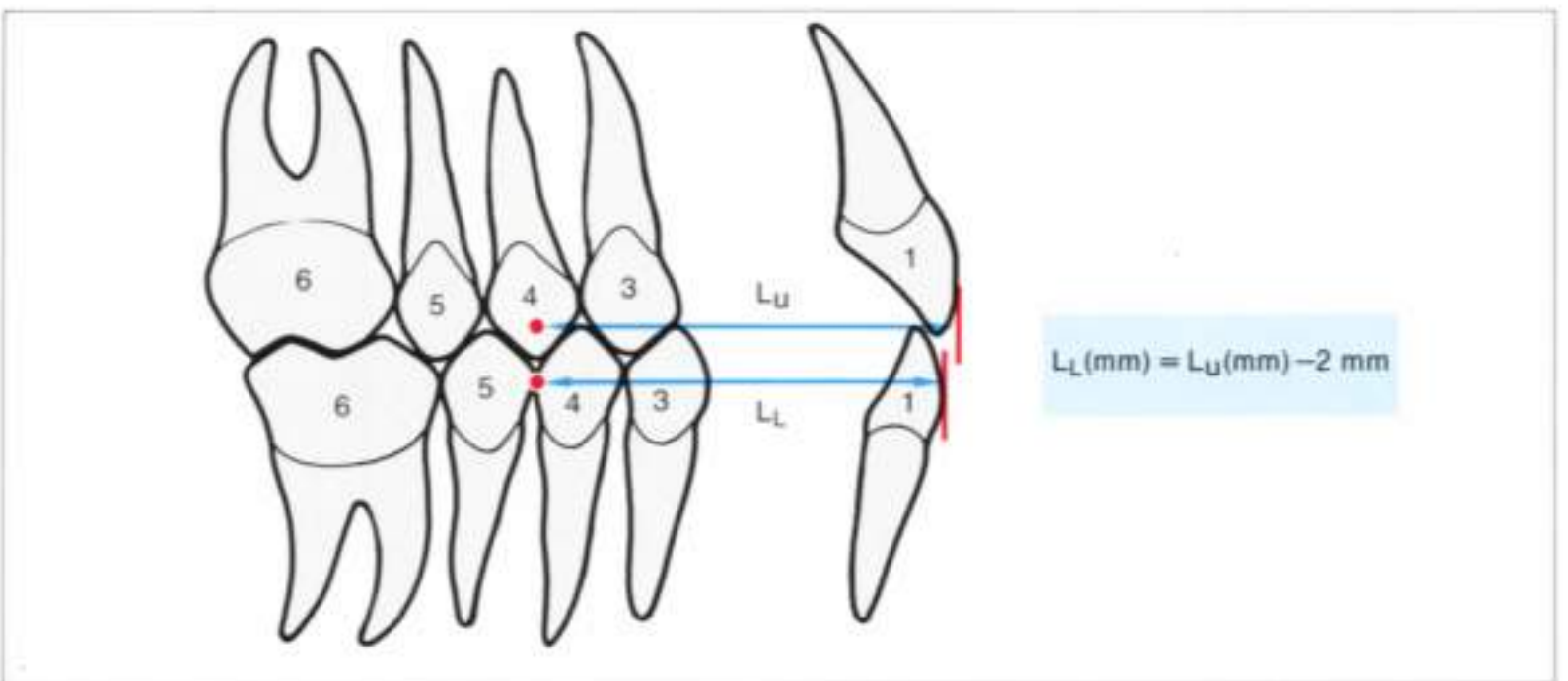




505 Measurements of anterior arch length

Overview of the maxillary and mandibular arches, with marking of the reference lines for anterior arch length determination.

The arch length is defined as the distance perpendicular to the line connecting the reference points of anterior arch width in the midsagittal plane. It is measured from the intersection of the two lines to the labial surface of the most anteriorpositioned central incisor.



506 Correlation between maxillary and mandibular anterior arch lengths

Schematic illustration of the anterior arch length of the maxilla and mandible in the anteroposterior plane. In normal occlusion, the measuring points of both jaws lie directly across from one another.

The anterior arch length of the mandible (L_L) is shorter than the maxillary arch length (L_U) by the labiolingual width of the incisal edge of the upper central incisor. As a rule the following relationship applies: standard value L_L = standard value L_U – 2 mm.

507 Correlation table between the sum of the maxillary incisors and the maxillary anterior arch length

Standard values of the upper anterior arch length according to different investigators (figures in mm).

The formula for calculating the standard value of the upper anterior arch length, according to *Korkhaus* (1938), is as follows:

$$L_u = \frac{SI_u \times 100}{160}$$

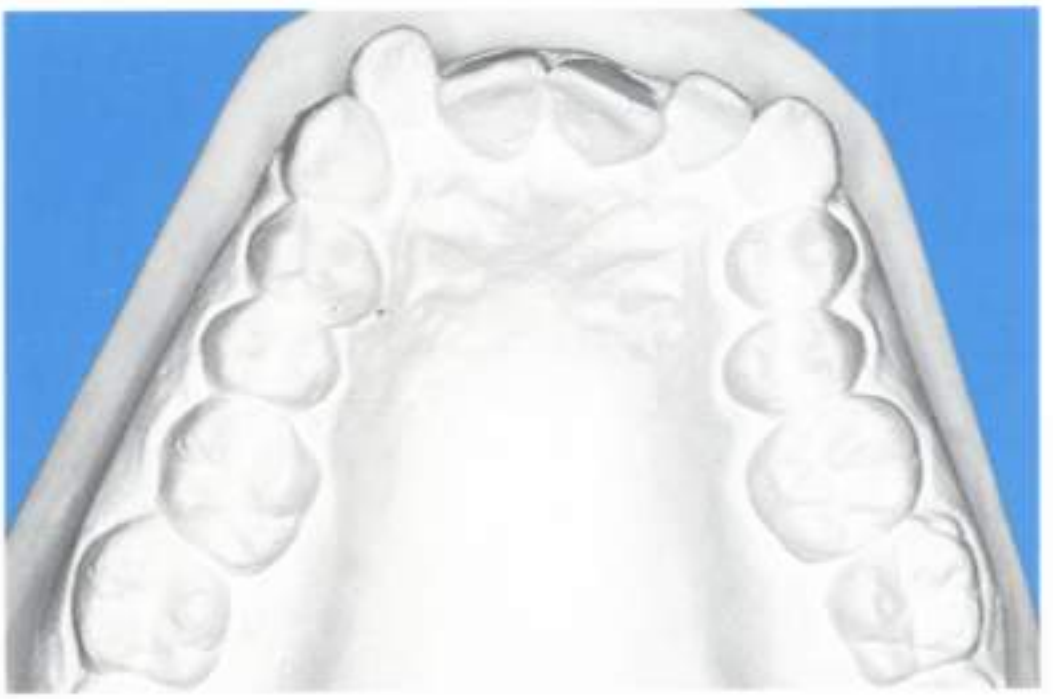
The measurement permits a crude analysis of the anteroposterior position of incisors.

SI_u	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33	33.5	34	34.5	35	35.5	36
Korkhaus	16	16.3	16.5	16.8	17	17.3	17.5	17.8	18	18.3	18.5	18.8	19	19.3	19.5	19.8	20	20.5	21
Weise	16.4	16.6	16.8	17.0	17.2	17.4	17.6	17.8	18.0	18.2	18.4	18.6	18.8	19.0	19.2	19.4	19.6	19.8	20.0
Brune	16.6	16.8	16.9	17.1	17.2	17.3	17.5	17.6	17.8	17.9	18.0	18.2	18.4	18.6	18.7	18.8	18.9	19.0	19.2

Shortened arch length

508 Linguoversion of central incisors

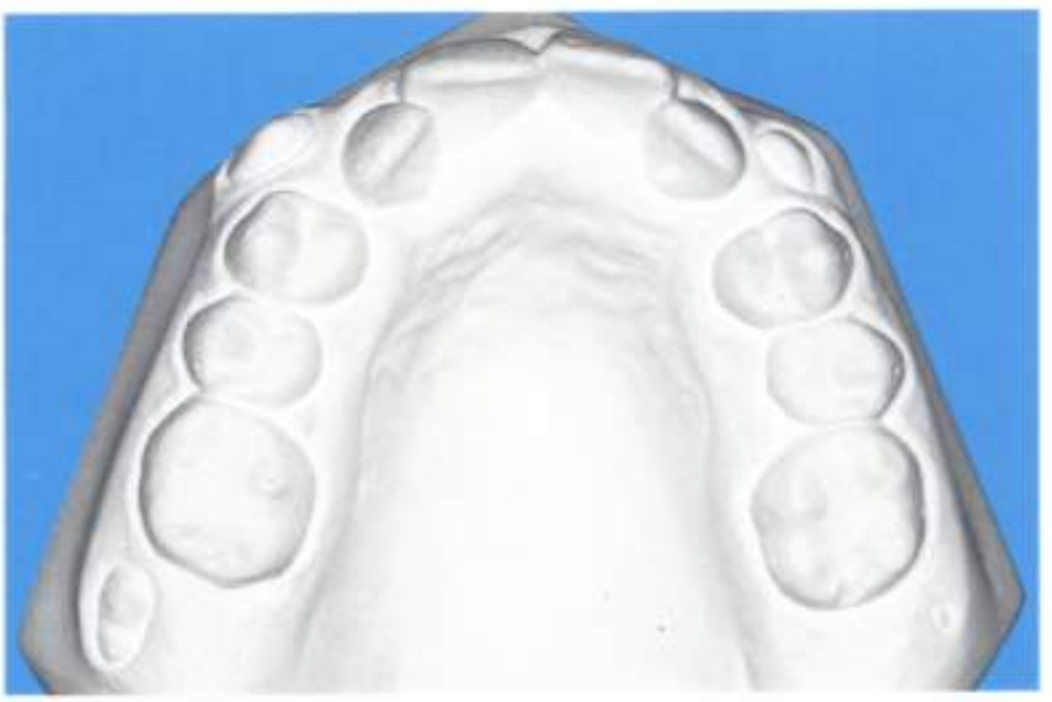
Shortened anterior arch length in the maxilla resulting from lingual inclination of upper central incisors in a Class II, Division 2 malocclusion.



509 Mesial position of premolars

Markedly shortened anterior arch length in the maxilla as the result of mesial drift of posterior teeth following early loss of deciduous teeth in the supporting zones.

The axial inclination of the upper incisors is approximately correct, in spite of a reduced L_u.



510 Interpretation of measurements of anterior arch length

A shortened or elongated anterior arch length is not always the result of an anteroposterior malpositioning of the incisors.

Finding		Anterior arch length
• Bilateral mesioversion of posterior teeth	→	L_U/L_L shortened
• Linguoversion of anterior teeth	→	L_U/L_L shortened
• Labioversion of anterior teeth	→	L_U/L_L increased
• Bimaxillary dental protrusion	→	L_U+L_L increased
• Distoversion of premolars	→	L_U/L_L increased
• Mandibular prognathism	→	L_L increased

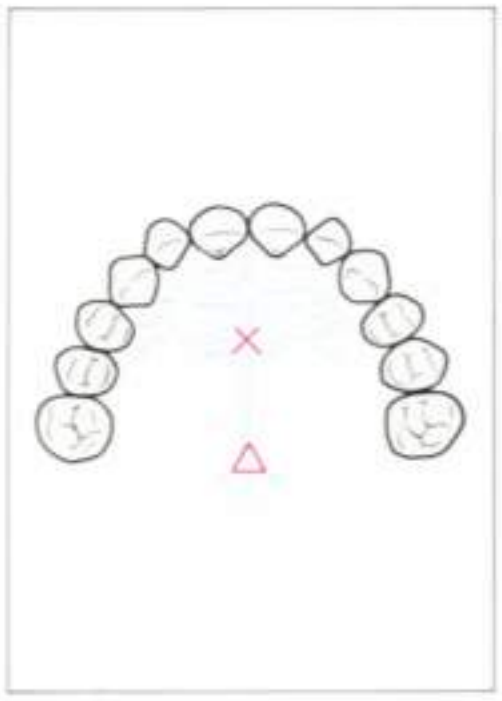
Intramaxillary Symmetry

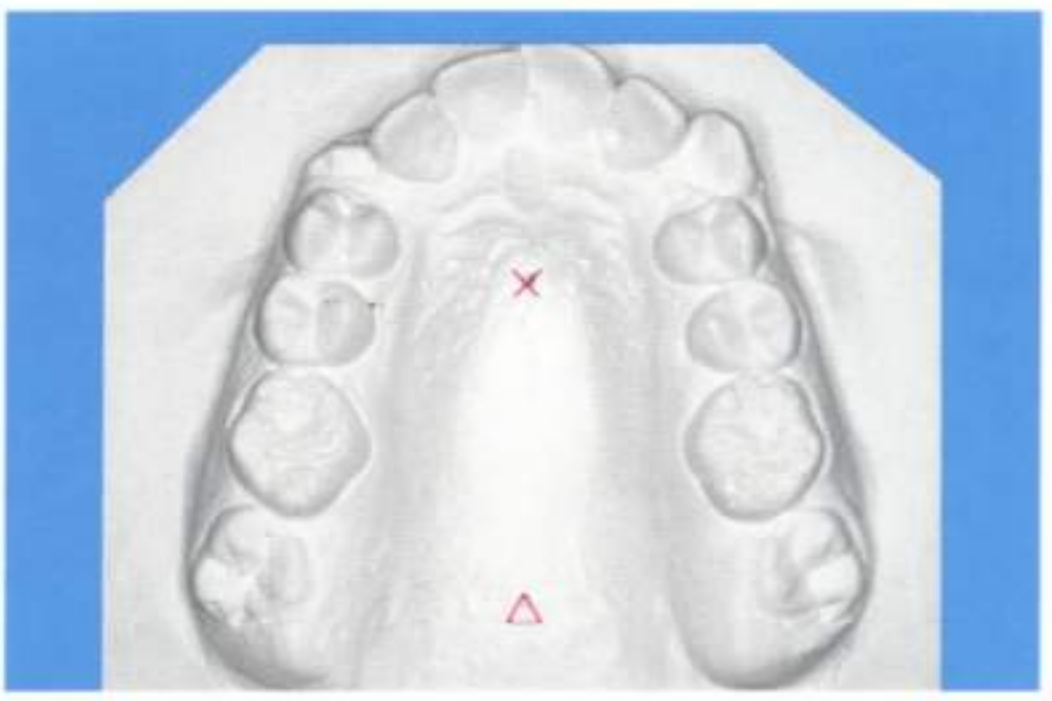
- Transverse symmetry
- Anteroposterior symmetry

These symmetry analyses estimate the right-left differences in transverse and anteroposterior tooth positions (Körbitz 1909).

For performing these measurements, precisely defined reference planes are necessary. The midpalatal raphe (midline of the maxilla) which is defined by two anatomical points on the palatine raphe is the reference plane for the transverse symmetry analysis. Construction of the *mandibular midline* is more difficult. The direct transference of the midpalatal raphe is of minor accuracy. It is more precise to mark the anterior point of the mandibular midline using the mental spine film (p. 171) or by using the lingual frenum (Korkhaus 1939). The posterior point for construction of the mandibular midline is determined by a perpendicular, which runs from the posterior edge of the midpalatal raphe from the maxillary to the mandibular cast.

The tuberosity plane is the reference plane for comparing anteroposterior symmetry. This plane is perpendicular to the midpalatal raphe and runs through the distal-most tuberosity.



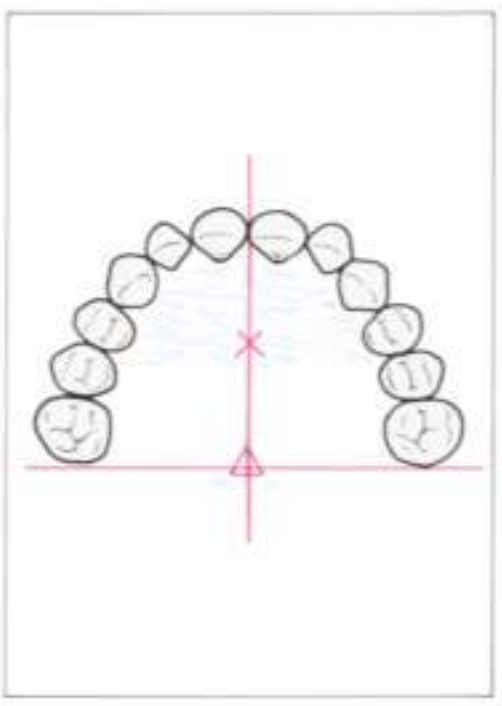


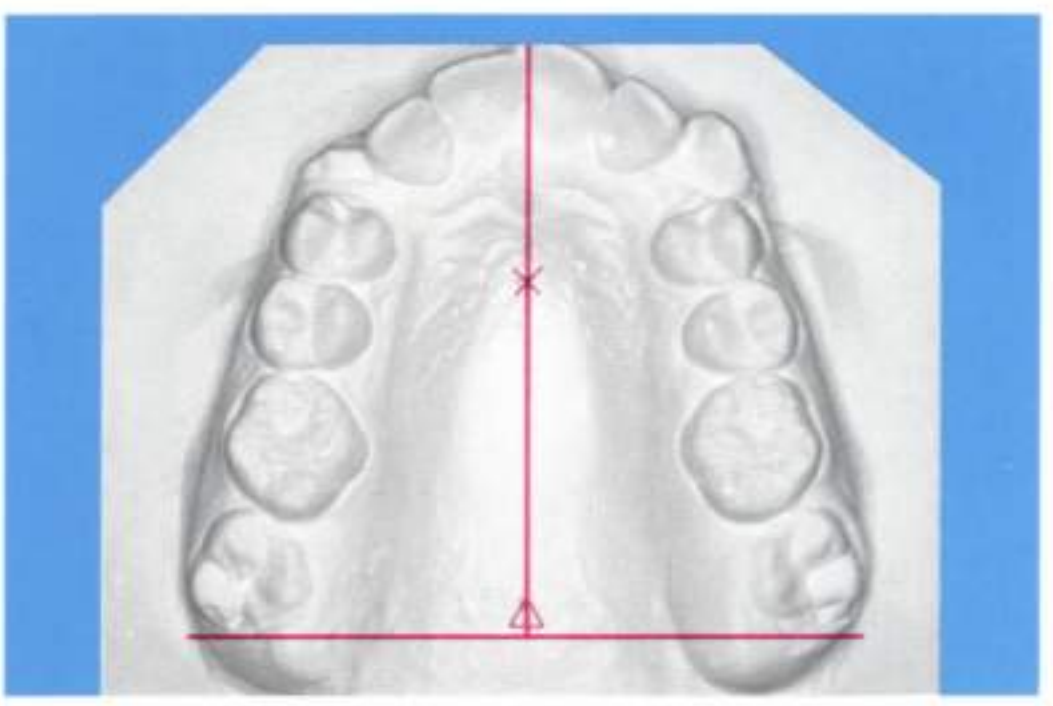
Construction of the reference planes

511 Midpalatal raphe
The midpalatal raphe is constructed with the help of two anatomic reference points on the palatine raphe.

Anterior point: (X): Cross-section of the second palatine rugae with the palatine raphe.

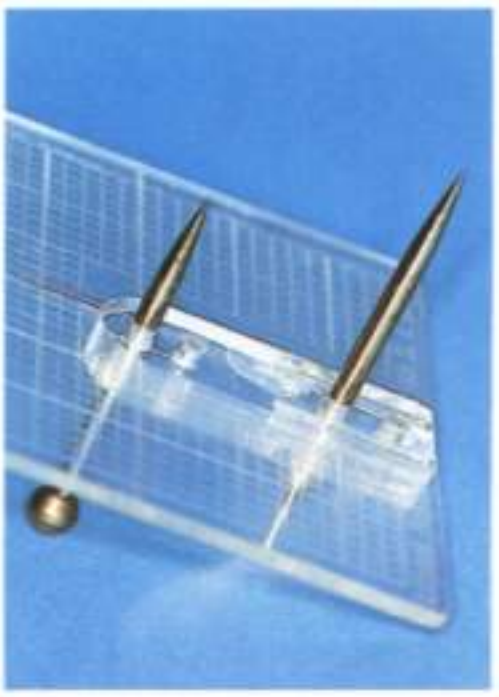
Posterior point: (Δ): The border of the hard and soft palate on the raphe respectively the midpoint between the paired foveolae, next to the raphe in this segment.

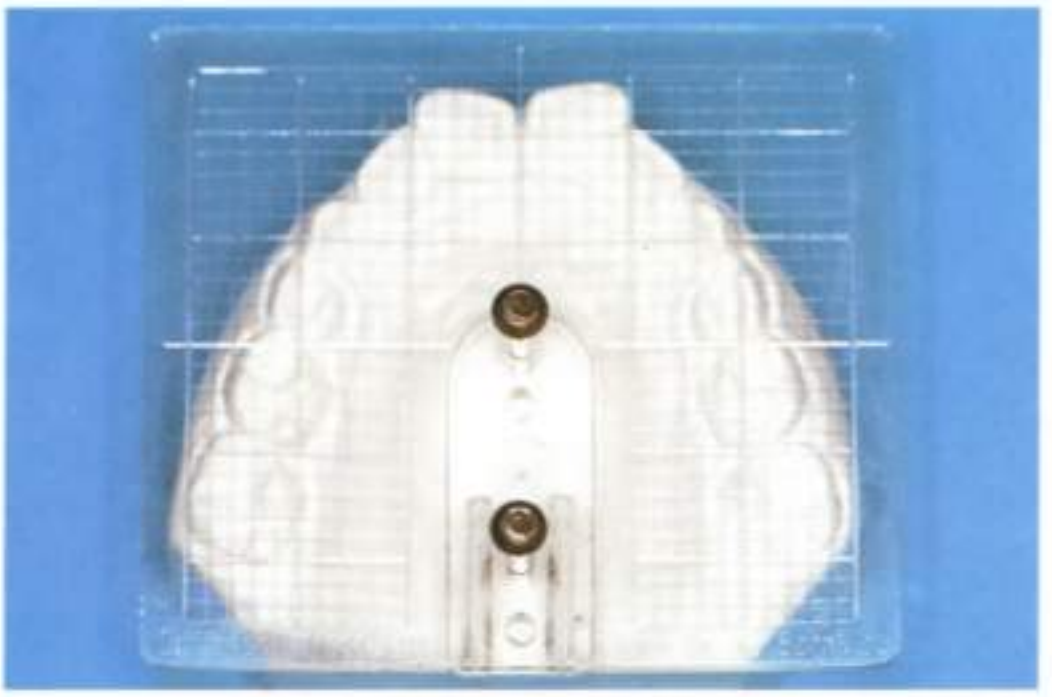




512 Marking of the reference planes
Construction of midpalatal raphe (MPR) through anatomically defined midpoints on the palatine raphe of the maxilla. The MPR is the maxillary midline and reference plane for assessing transverse symmetry.

The anteroposterior symmetry assessment is made using the relationship to the tuberosity plane which is perpendicular to the MPR and extends through the most distally positioned maxillary tuberosity.





513 Symmetrograph according to Bernklau
Asymmetrical arch shape in transverse and anteroposterior directions, can be assessed using appropriate measuring instruments which are oriented to the midpalatal raphe and tuberosity plane.

The transparent measuring grid of *Bernklau* is a plastic template with a 2-mm square scale and two metal rods. The calibrated grid can therefore be sturdily fixed on the midpalatal raphe.

Left: Oblique side view of the measuring grid.

Analysis of Transverse Symmetry

The following findings are derived from this type of intramaxillary assessment of the study casts.

- Symmetric/asymmetric width development between right and left sides of the arch (malposition: symmetric, asymmetric, unilateral)
- Congruence/incongruence between dental midline and skeletal midline of the arches (dental midline shift)

The transverse distance of the Pont reference points to the arch midline is determined and the actual measured value is compared with the half value of the standard width of the dental arch. According to Schmuth (1983), measurements should not be taken from these reference points but rather from the linguo-gingival margin of the teeth, since erroneous measurements can occur in cases of tooth rotation.

From a diagnostic point of view, assessment of the transverse symmetry is clinically relevant, particularly in cases of transverse malocclusions (lateral cross-bite, edge-to-edge occlusion, buccal/lingual nonocclusion).

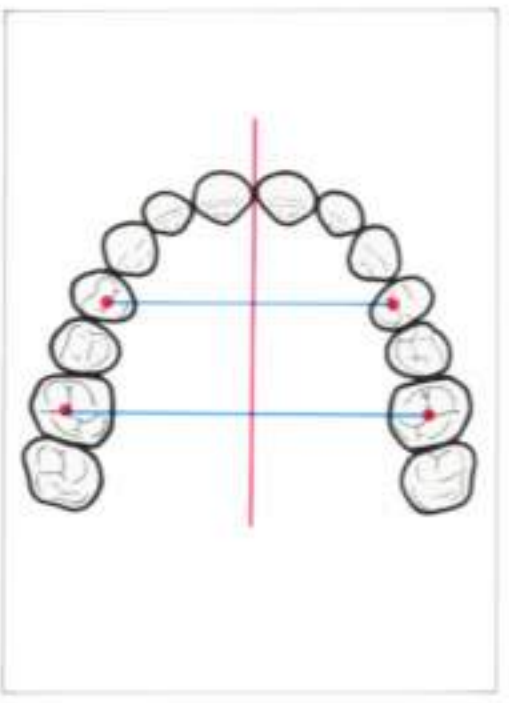
Clinical importance of transverse symmetry analysis – case example –

514 Unilateral cross-bite
Transverse malocclusion in the right posterior region, with mandibular midline shift of approximately 1.5 mm to the right.

For assessing the cause of this malrelationship, the transverse symmetry analysis should be carried out first to determine the significance of a right-left asymmetry in the upper and lower arch width.

515 Symmetric maxillary arch
Comparing transverse symmetry, the right and left arch sides are of equal width in relation to the midpalatal raphe. Maxillary arch of the case example shown in Fig. 514.

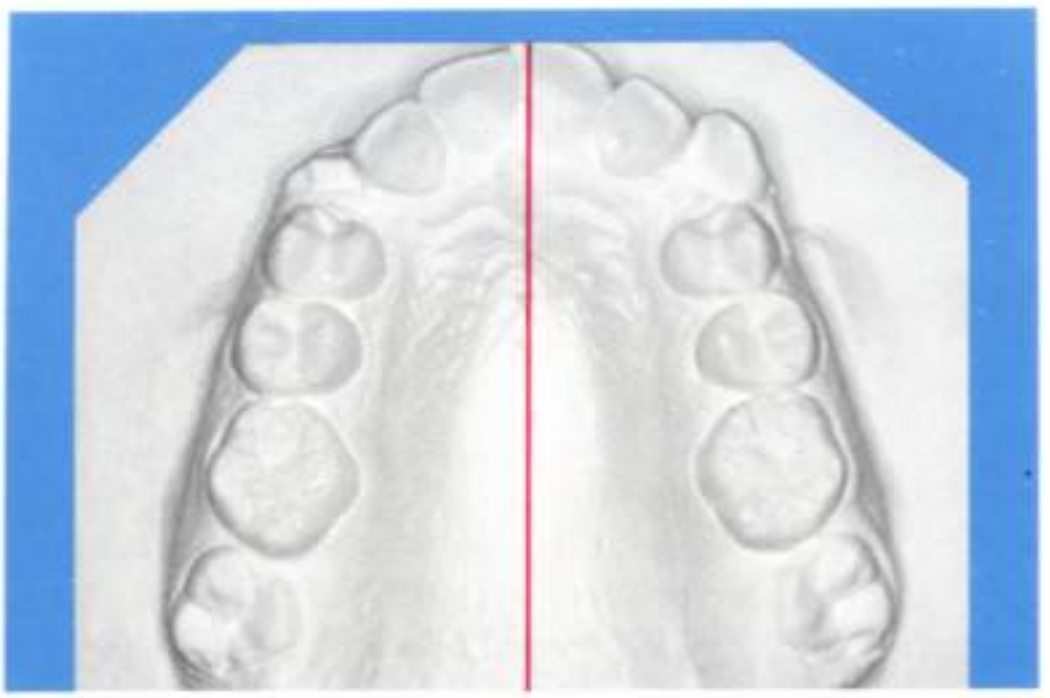
Right: Line-drawing of the relevant midsagittal plane. As a rule, transverse symmetry is assessed using the Pont reference points.



516 Asymmetric mandibular arch
The lower arch shows asymmetric development between the left and right sides.

The distance of the right posterior teeth from the mandibular midline is greater than that of the other side.

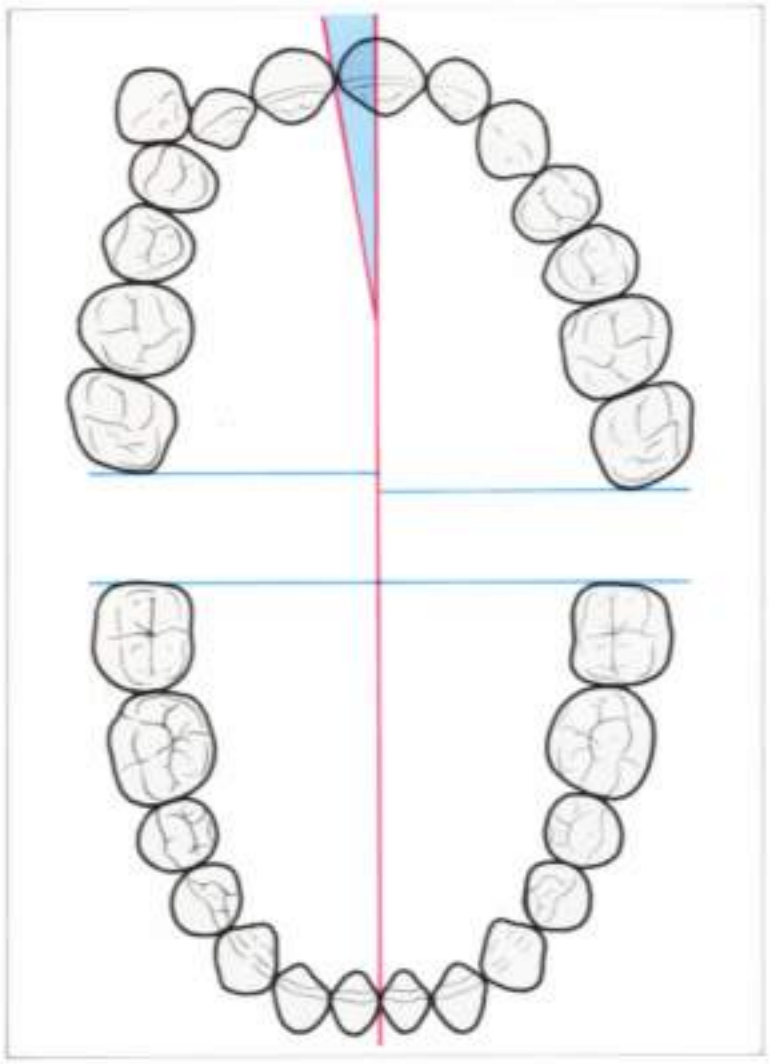
Thus, according to this analysis, the unilateral cross-bite, shown in Fig. 514, is combined with unilateral excessive width of the lower right posterior arch.

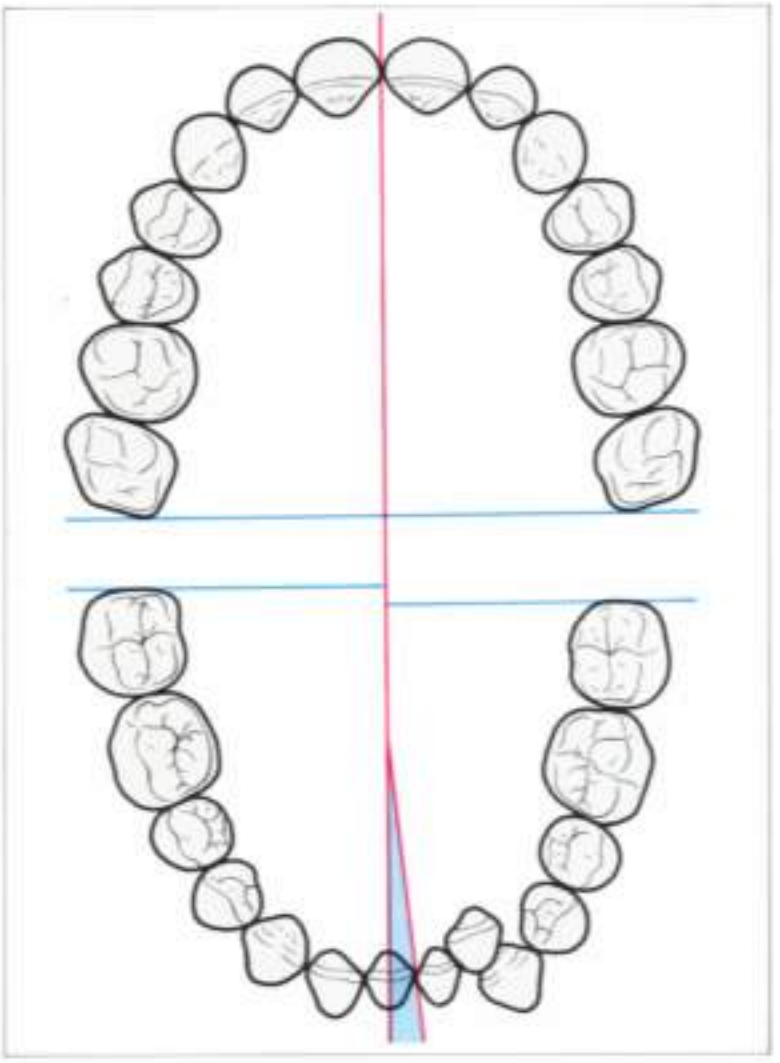


Midline shift

517 Midline shift in the maxillary arch
The contact point of the mesial approximal surfaces of the upper central incisors does not coincide with the midsagittal plane (= mid-palatal raphe) of the upper arch, but deviates to the right (dental midline shift to the right).

Left: Lateral tipping of the upper incisors is a clinical feature of a dental midline shift.



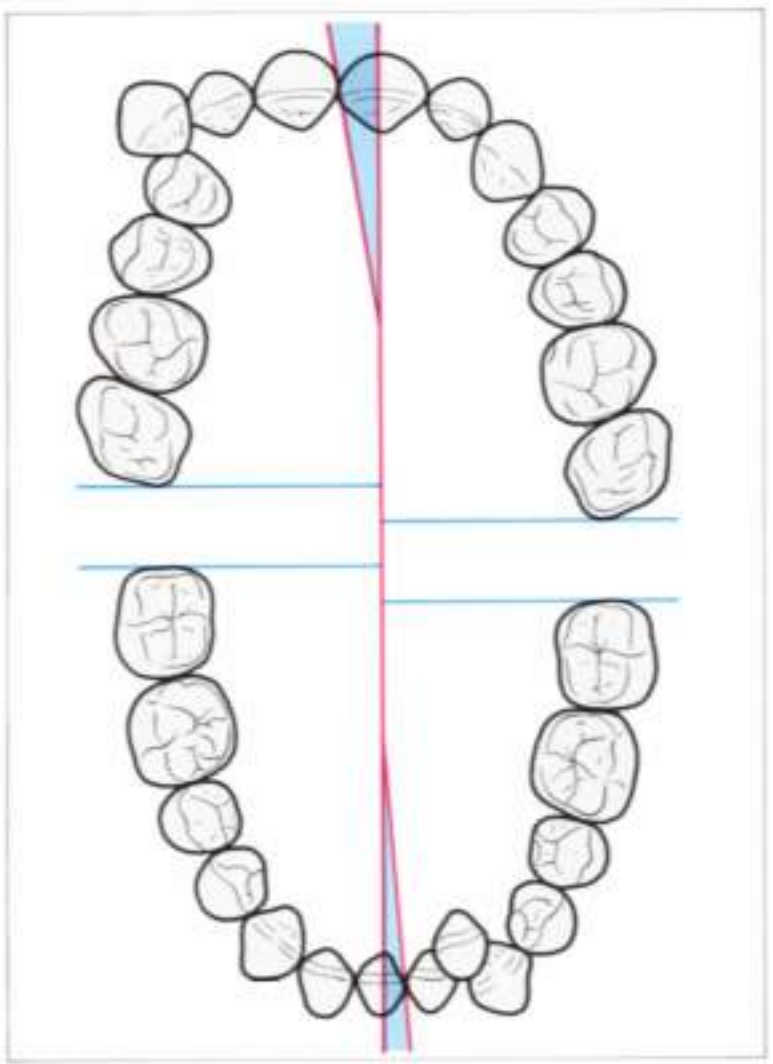


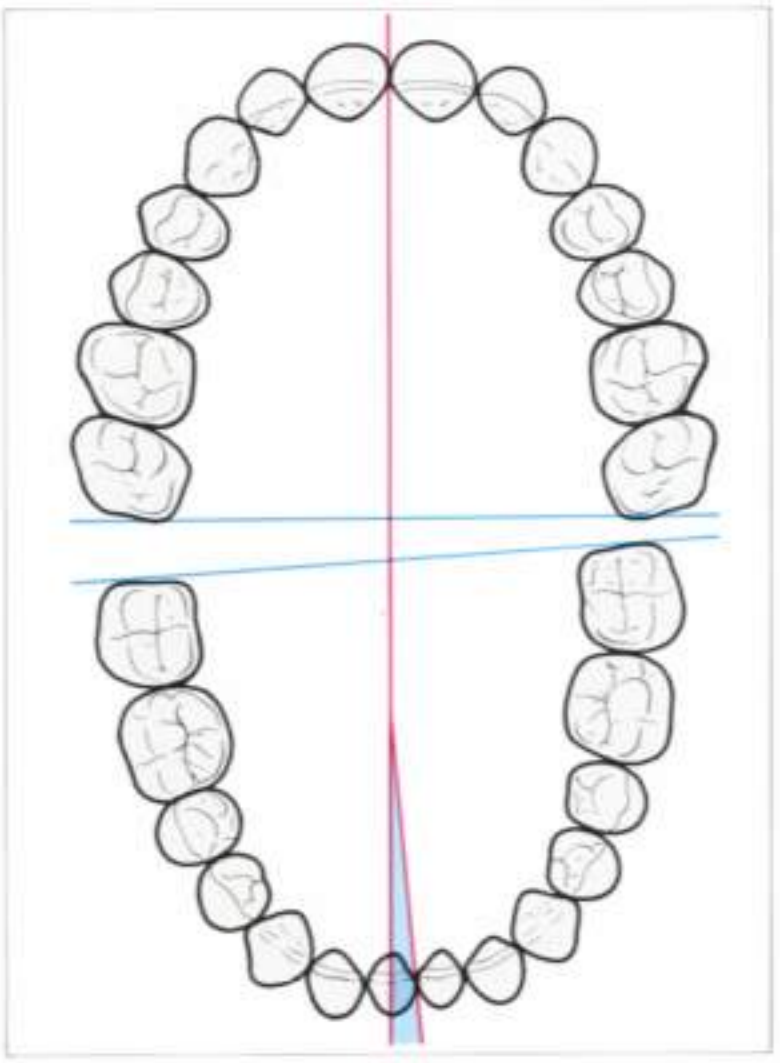
518 Dental midline shift
Dental midline shifts are the result of tooth migration.

Left: Dental midline deviation in the upper arch.

The contact point of the upper central incisors is shifted to the right, in relation to the midsagittal plane, i.e. to the side with lack of space for the canine.

Right: Dental midline shift in the mandibular arch. The contact point of the lower central incisors is deviated to the left as the result of tooth drift: in an otherwise well-aligned arch, the lower right lateral incisor is lingually blocked out (according to *Reichenbach* and *Brückel*, 1967).





519 Differentiation between dental and skeletal midline shift in the mandible
Left: Maxillary and mandibular arches with dental midline deviations in opposite directions in conjunction with tooth malpositioning in the respective anterior regions.

Right: Skeletal mandibular midline shift, as a result of displacement of the whole mandible to the left.

The MPR is not useful for differentiation between dental and mandibular midline deviation. The true skeletal mandibular midline has to be determined. The anterior skeletal midpoint of the mandible is either determined with the help of the mental spine view (see Fig. 431) or by assessing the point of insertion of the lingual frenum. The radiographic method is the most reliable.

Analysis of Anteroposterior Symmetry

The measurements reveal the following:

- Asymmetric mesiodistal tooth position of corresponding teeth in the right and left sides of the dental arches

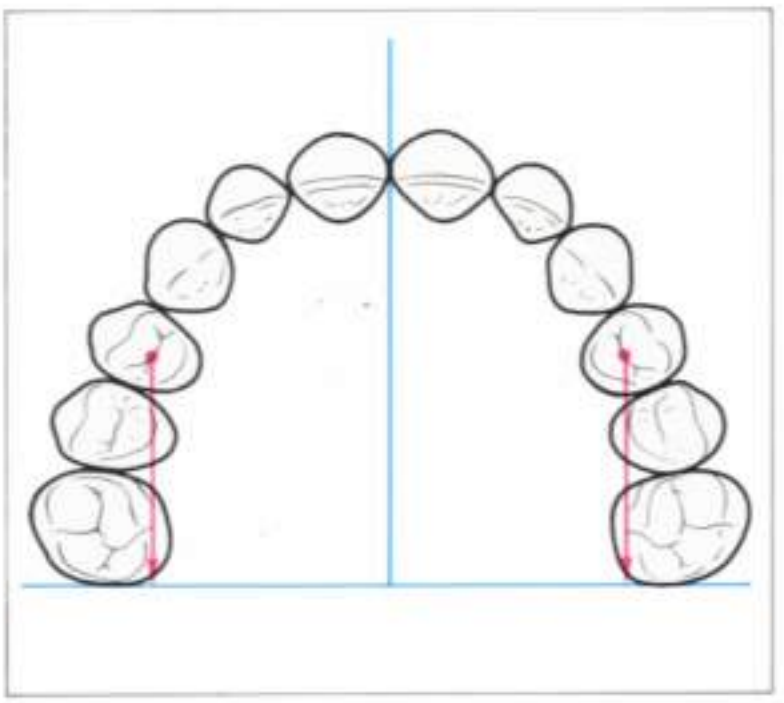
In practice, this involves drawing a line parallel to the tuberosity plane, which runs through the posterior surface of the distal-most first molar, and comparing the sagittal distances of the individual posterior teeth (it is postulated that the first molars only seldom migrate distally!).

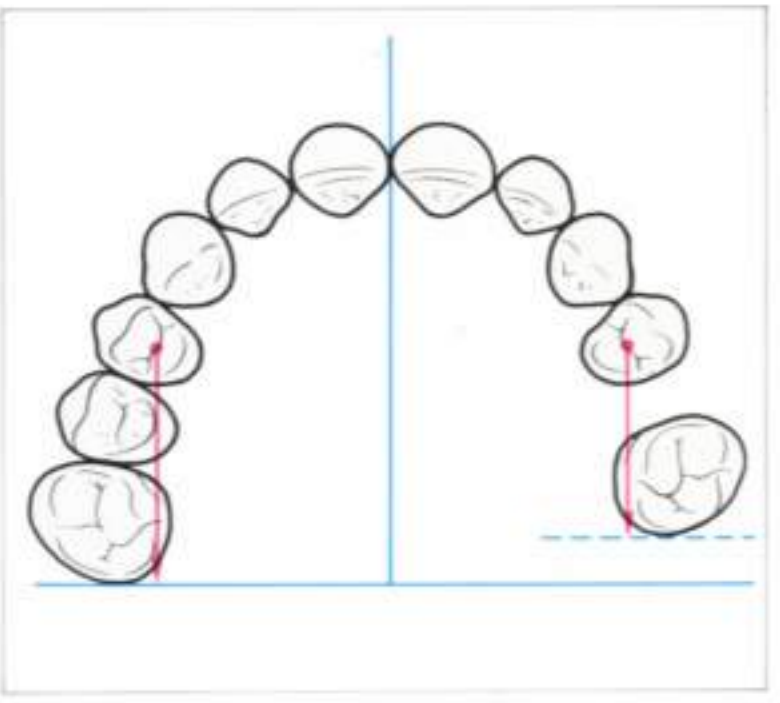
This analysis serves to diagnose first and foremost any mesial tooth drift. If there is no right – left asymmetry, the teeth are correctly positioned or there has been symmetric mesial migration. In this case, the diagnosis of the mesial tooth shift has to be made by assessing other criteria (Fig. 523).

Asymmetry of a transverse arch form may result in a relative mesial position of the more buccally placed teeth (characteristic symptoms of mesial malpositioning are absent in such a case).

520 Analysis of anterposterior symmetry
Left: Diagram of the normally developed arch showing the midsagittal plane, the tuberosity plane, and the distance of the first premolars from the tuberosity plane.

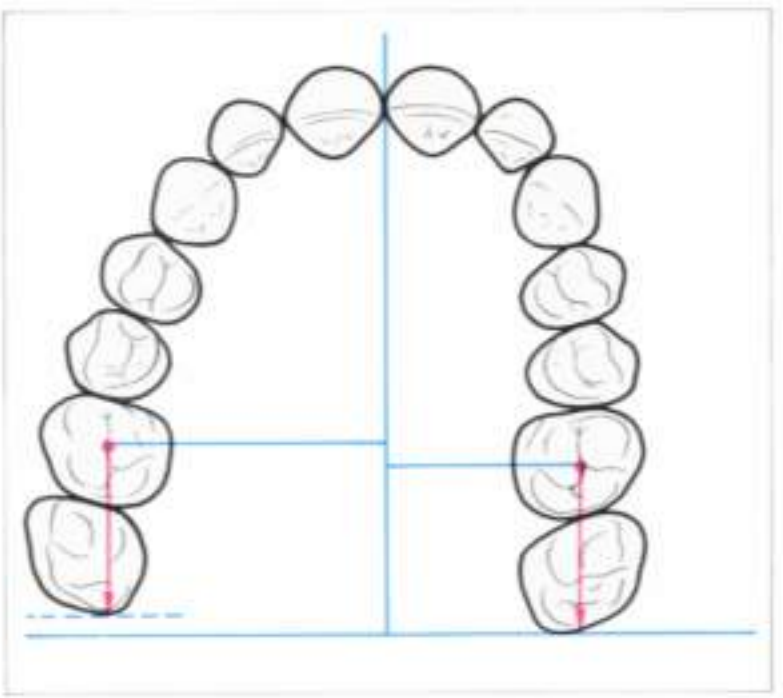
Right: Right-left discrepancy of the distance of the first molars from the tuberosity plane. The mesial drift of the upper left first permanent molar can be measured using this method. A prerequisite for this is that the opposite side of the dental arch is normally developed.





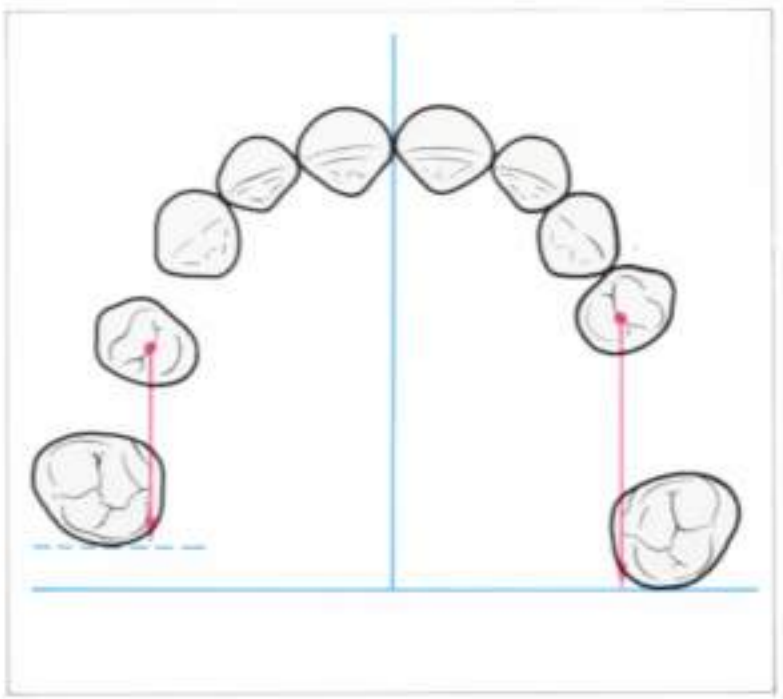
521 Correlation between anteroposterior and transverse tooth position
Asymmetric position of the first molar in the absence of mesial drift of the right posterior teeth. The cause of this divergency in anteroposterior direction is a right-left difference in transverse arch form.

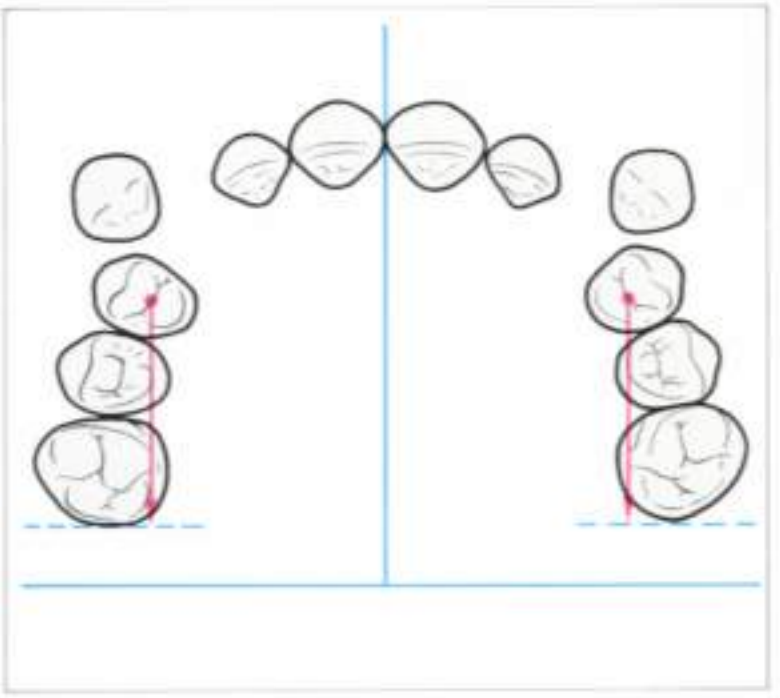
The more buccally placed teeth on the right side are relatively positioned more mesially as a result of the increased arch curvature.



522 Differentiation between unilateral and bilateral shift of posterior teeth
Left: Since the left arch is normally developed, migration of the first premolar and first molar on the right side can be measured in relationship to the tuberosity plane.

Right: In the case of bilateral migration of posterior teeth the position of the tuberosity plane is altered so that the symmetry analysis does not discover the malpositioning. An exact reconstructing of the original position of the tuberosity plane is very difficult.



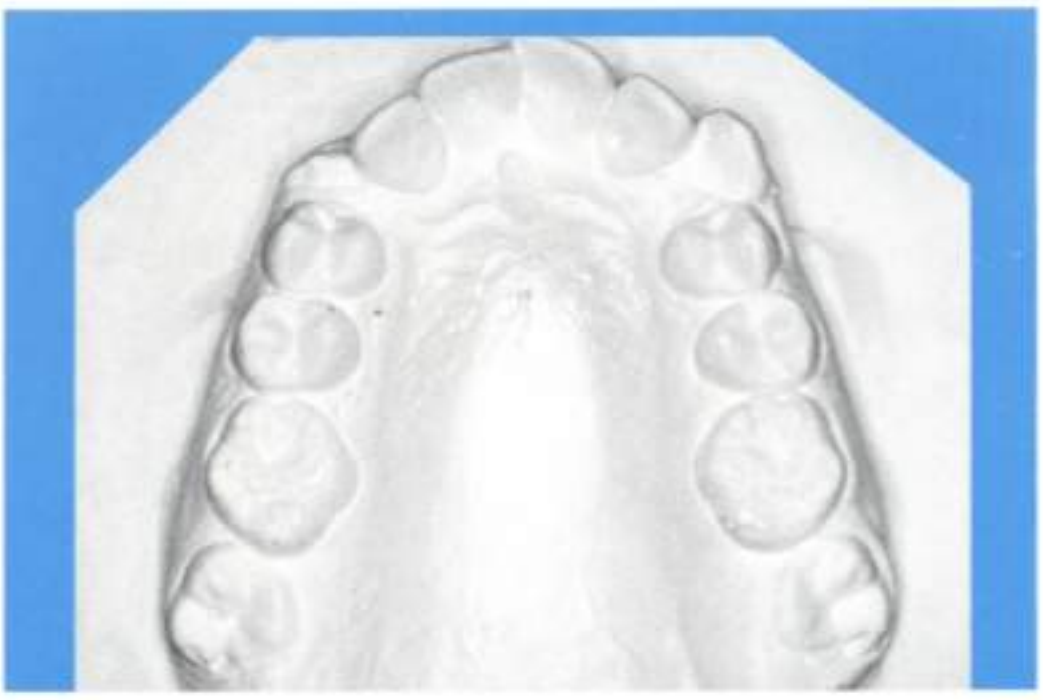


Symptoms of **Mesial Position** of Posterior Teeth

- Crowding and space loss, especially in the supporting zones
- Dental midline shift with crowding and space loss
- Mesial tipping of premolars
- Rotation of first permanent molars
- Relation of first pair of palatine rugae to the canine according to Hausser (first palatine rugae distal to canine = mesial position)
- Relationship of the papilla-transverse plane to the canine (Schmuth) (perpendicular through the posterior end of the incisive papilla runs distal to the canine = mesial position)

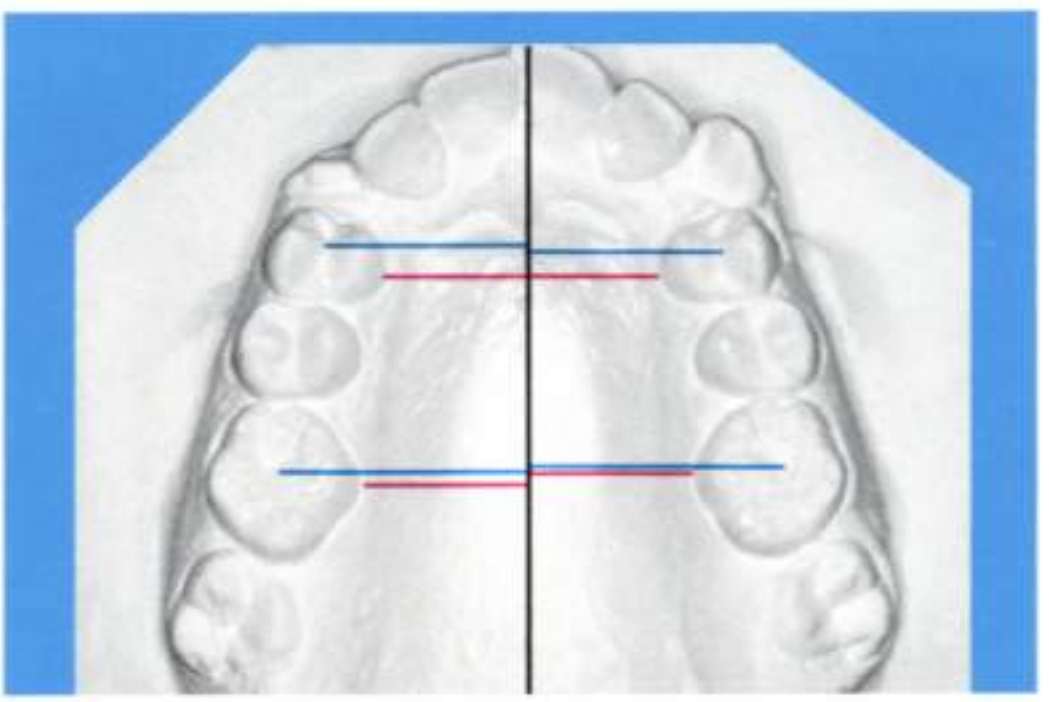
523 Symptoms of bilateral mesial position of posterior teeth

Qualitative and quantitative assessment for the diagnosis of mesial migration of right and left posterior teeth.



524 Rotation of molars

Bilateral mesial position of posterior teeth, clinically apparent by mesiolingual rotation of first permanent molars.

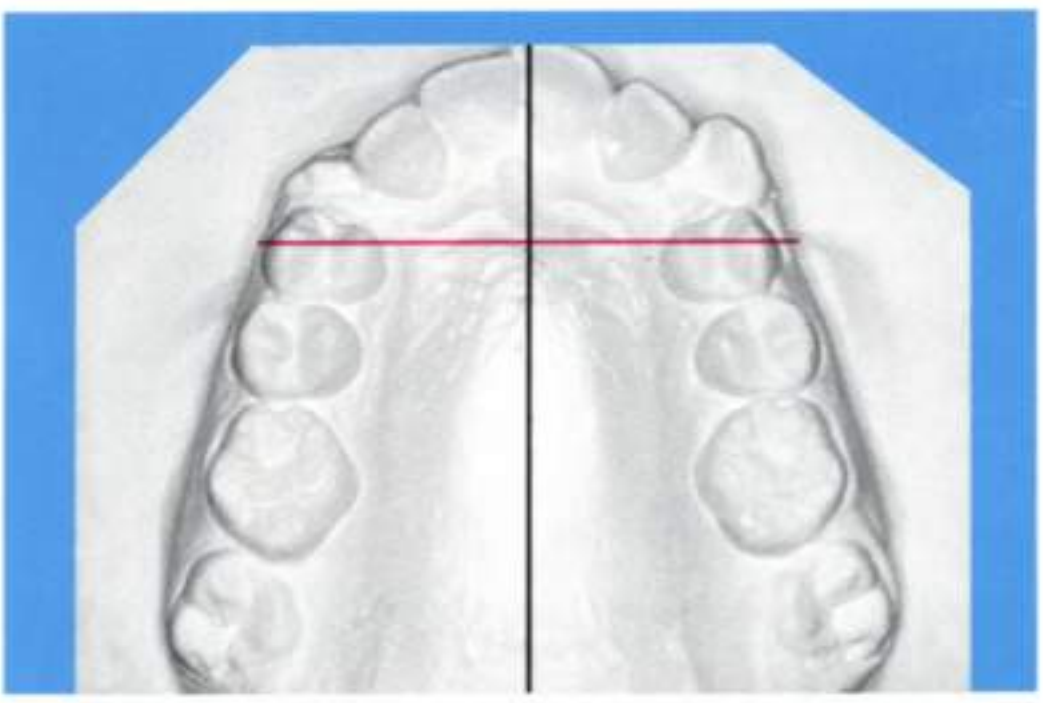


525 Anteroposterior symmetry in case of rotated molars

Blue = Normal case
Red = In case of tooth rotations

In cases with rotation of the first molars, the anteroposterior symmetry analysis should not be carried out using the Pont reference points.

In these cases, mesial migration must bei assessed by measurements to the mesial or distal lingual surfaces of the first permanent molar.



526 Transverse plane of incisive papilla

Description of mesial position of posterior teeth using the transverse plane of the incisive papilla according to *Schmuth*.

The perpendicular constructed on the midpalatal raphe at the posterior point of the incisive papilla runs through the first premolars.

In normal relations, the papilla-transverse line extends to the canines.

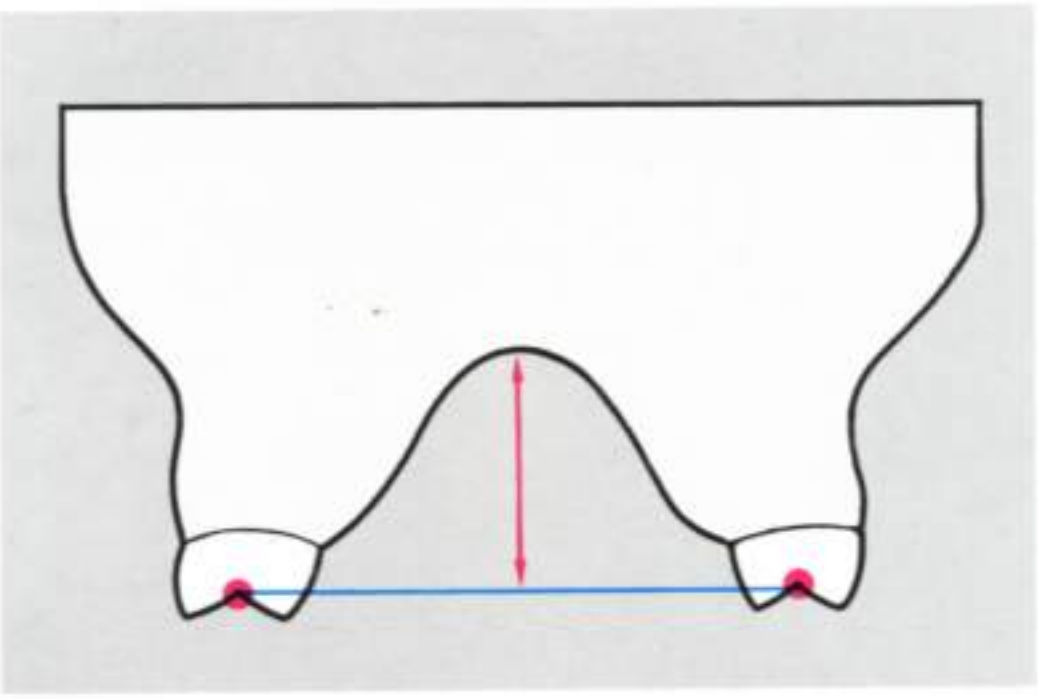
Palatal Height

Palatal height, according to Korkhaus, is defined as a vertical line perpendicular to the midpalatal raphe which runs from the surface of the palate to the level of the occlusal plane. This is measured between the reference points of the Pont-Index for the posterior arch width. Korkhaus (1939) evaluates palatal shape according to the index:

$$\text{Palatal height index} = \frac{\text{Palatal height} \times 100}{\text{Posterior arch width}}$$

The average index value is 42%. The index figure is increased when the palatal vault relative to the transverse arch development is high, and decreased when the palate is shallow.

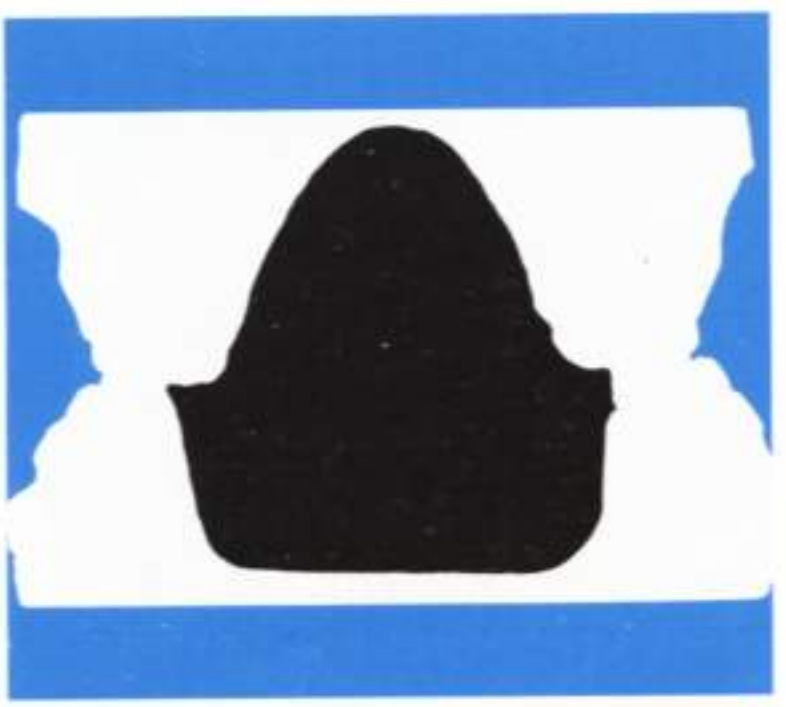
A high palate is a principal feature of apical narrowing of the maxillary alveolar process, which often occurs in cases of chronic mouth-breathing, rickets, and in certain types of sucking habits.



527 Palatal height index according to Korkhaus
Diagram of relevant lines for determining the palatal height index.

Palatal height is measured in the midsagittal plane in the region of the upper first molars, on the level of the occlusal plane. The height is defined as the distance of the perpendicular from the connecting line between the midpoint of the fissures of both upper first molars to the surface of the palate.

528 Measurement of palatal height
Using the Korkhaus three-dimensional orthodontic divider, the palatal height can be measured, as well as posterior arch width.



529 Palatal height in case of bilateral cross-bite
Transverse section of model casts in the first molar region.

Left: Bilateral cross-bite with a high palate (palatal height index = 51.3%). The palatal configuration is characteristic of bilateral narrowing of the maxillary arch. Treatment can include expansion of the upper dental arch.

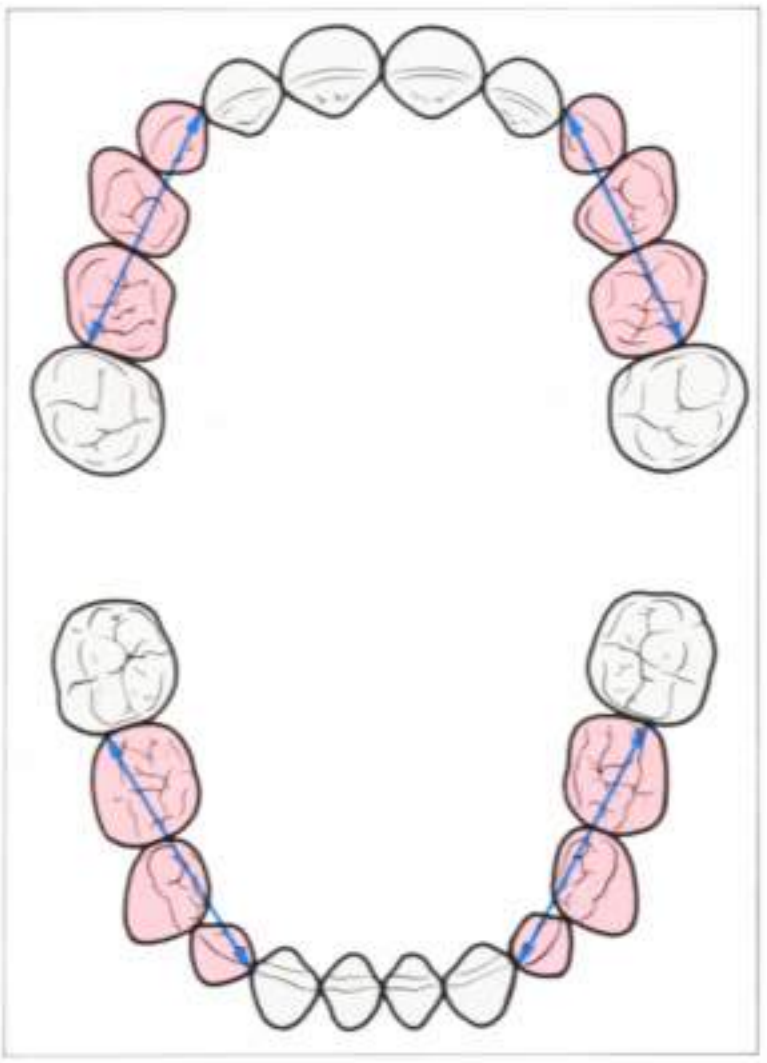
Right: Bilateral cross-bite with a shallow palatal arch (index = 36.6%). Extensive expansion of the upper dental arch would be contraindicated.

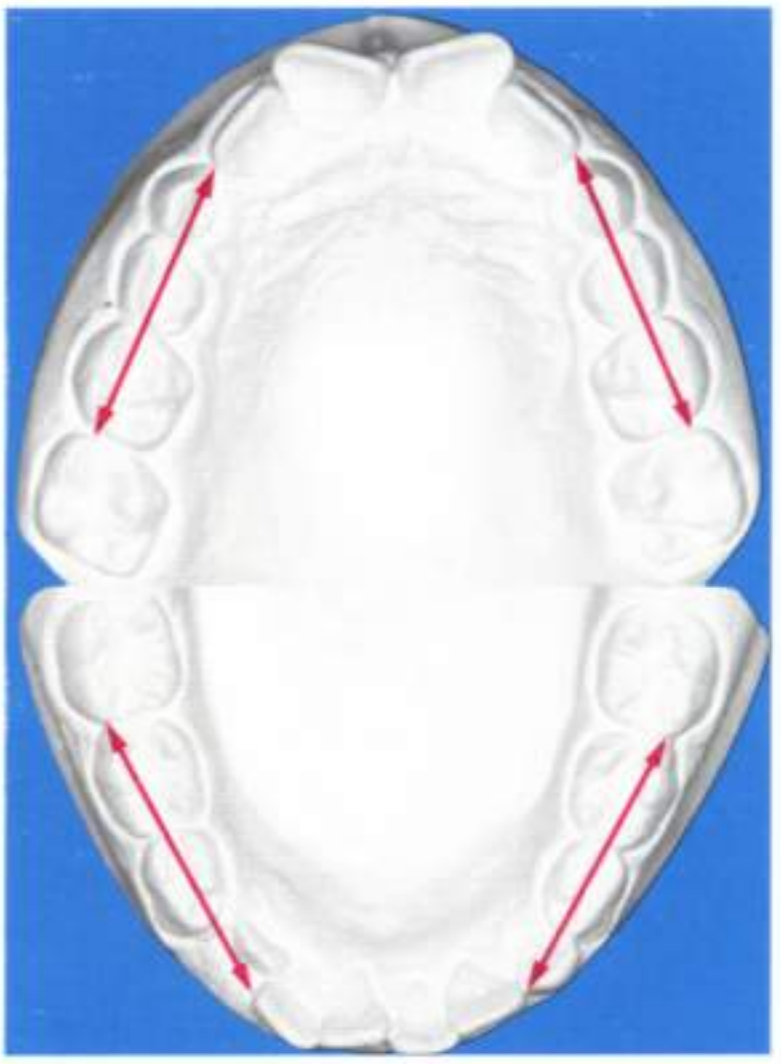
Analysis of Supporting Zones

Assessment of supporting zones (Fig. 530) is carried out in the mixed dentition period to determine the difference between space available and space required for the as yet unerupted permanent canines and first and second premolars. Four different methods of evaluation are described in the literature:

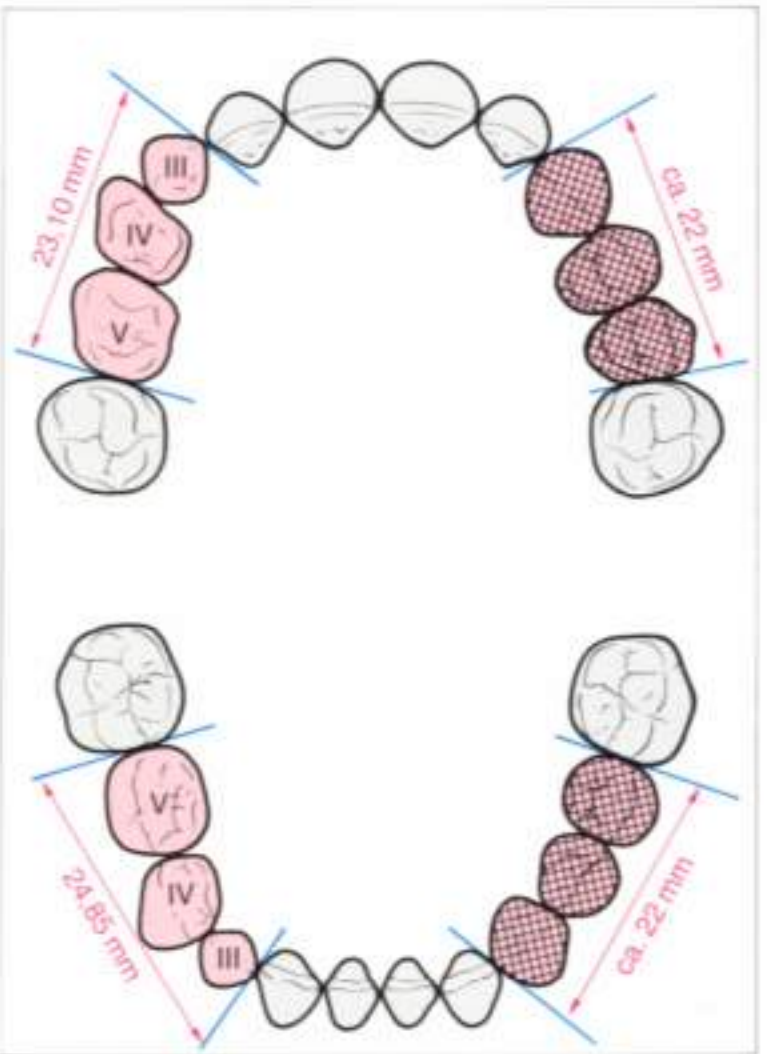
- A prediction method based on mean values for supporting zones
- Proportionality tables taking into account size of the anterior teeth
- Radiologic methods
- Combination of radiologic and prediction table methods

The combined radiologic-prediction table method estimates the width of the unerupted teeth most accurately. The prediction from proportionality tables is the next most accurate method. The radiologic determination is the least accurate, because of technical difficulties. The prediction tables are the most widely used in clinical practice.





530 Measurement of the supporting zones
The supporting zone in the mixed dentition is defined as the distance between the distal surface of the lateral permanent incisor and the mesial surface of the first permanent molar. The area comprises the deciduous canine and the first and second deciduous molars.



Average values of the supporting zone

	♂		♀	
	max	mand	max	mand
Seipel (1946)	22.3	21.8	21.0	21.1
Moorrees (1957)	21.8	21.8	21.2	20.6
Stähle (1958)	21.9	21.6	21.7	21.1
Garn (1964)	21.9	21.5	21.0	20.6
Miethke (1972)	21.8	21.4	21.1	20.7
Mean value	21.9	21.5	21.1	20.7

531 Supporting zones – mean values
Left: Comparison of distances: distal edge of the lateral permanent incisor to the mesial edge of the first permanent molar in the mixed dentition *(left)* and in the permanent dentition *(right)*. Mean values according to *A.M. Schwarz*.

The additional space which occurs in the supporting zone during the transitional period is known as the *"leeway space"* (Nance). It is larger in the mandibular than in the maxillary arch.

Right: Average values for the supporting zones in males and females according to different investigators (*Schulze* 1982).

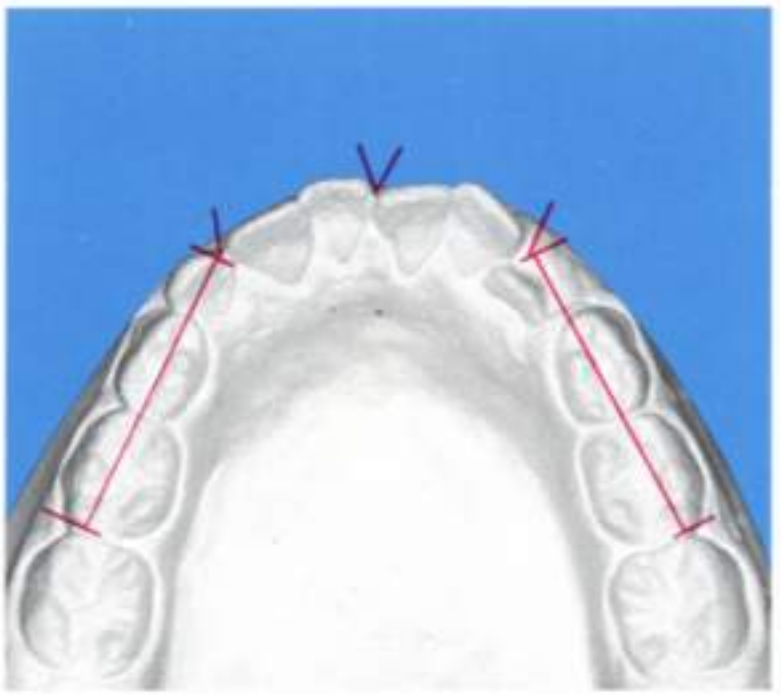
Prediction from Proportionality Tables

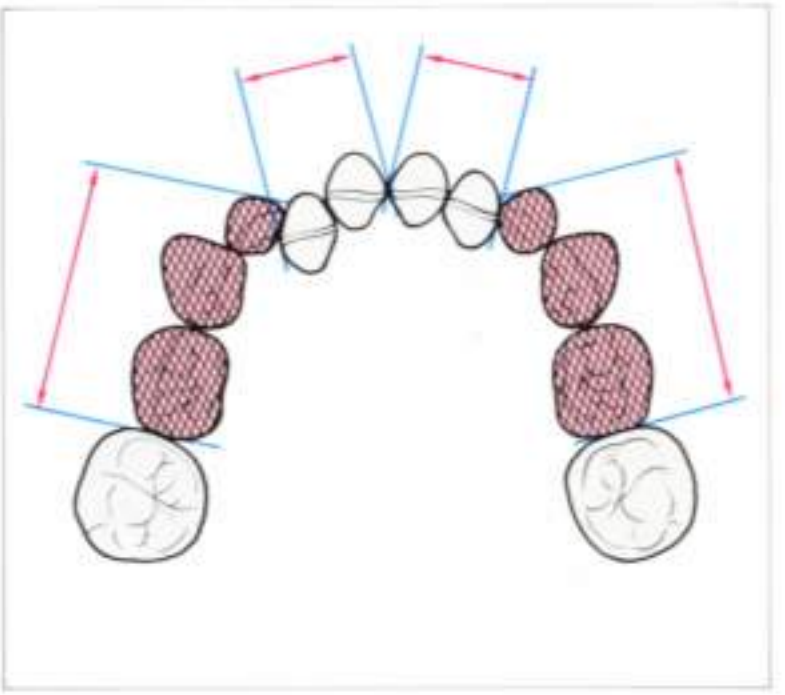
The best known predication tables for estimating the required space of unerupted permanent canines and first and second premolars is that of Moyers (1967); it is used as follows:

1) Determination of the sum of mesiodistal tooth width of lower permanent incisors (SI_L).
2) In the presence of incisor crowding: marking the distance of incisor width in the line of arch for each quadrant starting from the contact point of lower central incisors (Fig. 532).
3) Measurement of the distance from the mark in the anterior region (in a well-formed anterior arch from the distal surface of the lateral permanent incisor) to the mesial surface of the first molar (space available).
4) Reading off the probable space requirement for the permanent canine and first and second premolars from the prediction table using the column which shows the measured width of lower incisors.
5) The difference between available space and space required expresses the space situation in millimeters; in case of insufficient space, by a minus value.
6) Steps 2 to 5 are repeated for the maxillary arch.

532 Measurement of supporting zones in case of incisor crowding
In each quadrant the sum of the width of central and lateral incisors is measured with a tooth-measuring gauge from the contact point of the central incisors and marked. In cases of crowding the marking may extend to the canine.

The actual length of the supporting zone is defined as the distance between this mark and the mesial edge of the first permanent molar. The procedure is performed separately for the right and left sides.





533 Prediction values from proportionality tables
Prognosis of width of permanent canine and first and second premolars in relation to the sum of the mandibular incisors (SI_L). The level of probability with this method is 75%.

Based on the actual value of the SI_L, the predicted space requirement for the unerupted teeth of the supporting zones in the mandibular and maxillary arch can be read off (*Moyers* [USA], *Droschl* et al. [Austria]).

$\overline{345}$ 75%-Level of probability

SI_L		19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0
Moyers		20.1	20.4	20.7	21.0	21.3	21.6	21.9	22.2	22.5	22.8	23.1	23.4	23.7	24.0	24.3	24.6
Droschl	♂	20.8	21.0	21.2	21.4	21.6	21.8	22.0	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.7	23.9
	♀	20.0	20.3	20.6	20.8	21.1	21.4	21.6	21.9	22.2	22.4	22.7	23.0	23.2	23.5	23.7	24.0

$\underline{345}$ 75%-Level of probability

SI_L		19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0
Moyers		20.6	20.9	21.2	21.5	21.8	22.0	22.3	22.6	22.9	23.1	23.4	23.7	24.0	24.2	24.5	24.8
Droschl	♂	21.3	21.5	21.7	21.9	22.0	22.2	22.4	22.6	22.7	22.9	23.1	23.3	23.4	23.6	23.8	24.0
	♀	20.2	20.5	20.7	21.0	24.0	21.2	21.5	21.7	22.0	22.2	22.5	22.7	23.0	23.2	23.5	23.7

534 Chart for space analysis in the mixed dentition using proportionality tables
The space available correlates with the values from the cast of supporting zone length.

Required space is the predicted value taken from the tables for the sum of the width of the permanent canine and the first and second premolars.

Tooth	42	41	31	32
Mesiodistal width				
Total width (SI_L)				

	Lower arch right	Lower arch left	Upper arch right	Upper arch left
Space available after incisor alignment				
Space required				
Difference				
Discrepancy/arch				

Combined Radiologic-Prediction Table Method

This procedure combines measurements from the dental cast and width measurements from the periapical radiograph in order to improve accuracy of prediction for each individual case.

The method of Hixon and Oldfather (1956), modified by Staley and Kerbers (1980) is restricted to the analysis of the supporting zone in the mandible.

The procedure is as follows:

1) Measurement of size of unerupted first and second premolars in one mandibular quadrant from a periapical radiograph.
2) Determination of mesiodistal tooth width of the lower central and lateral incisiors on the study cast corresponding to the side of the radiograph.
3) After adding together both figures, the probable width of the permanent canine and first and second premolars for the corresponding quadrant can be read off in the prediction graph under the column of the calculated sum total (Fig. 536).

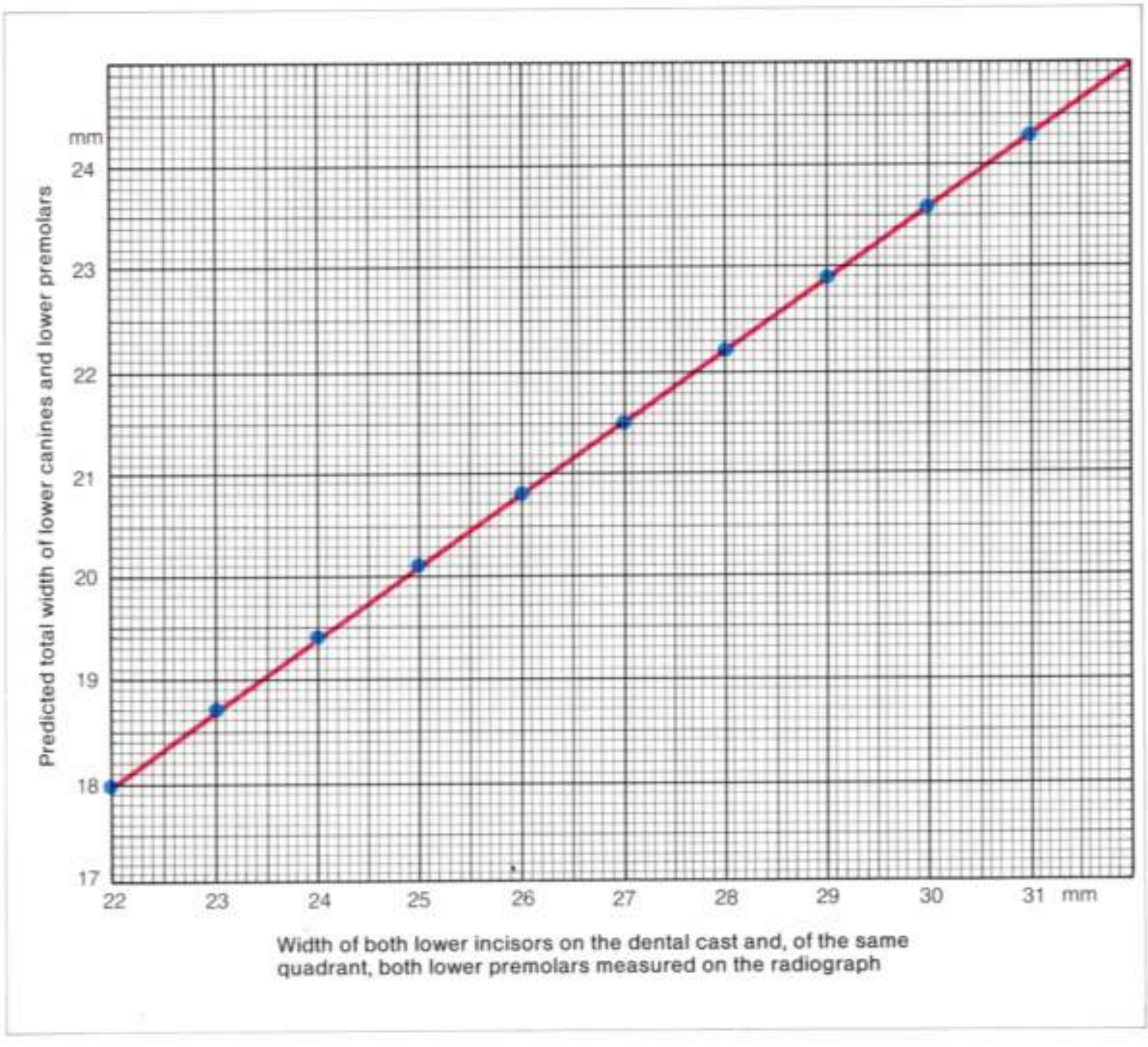
An optimal periapical radiograph taken with the long-cone technique under standard conditions (head and tube position), is necessary for this type of analysis of the supporting zone.

Measurement on dental cast			Radiologic measurement		
Tooth width:	mand 1:	mand 2:	Tooth width:	mand 4:	mand 5:
Total width:		mm	Total width:		mm

Total width model/film measurement:	mm
Space required:	mm
Space available:	mm
Difference/Quadrant:	mm

535 Chart for combined radiologic-prediction table method.
From the same side of the mandibular cast, the total width of the central and lateral incisors is measured. From the radiograph, the total size of the first and second premolars is determined.

Using the summed-up value of both measurements, the prediction graph gives the figures of the total width of canine and premolars of the same side (space required). Space available is the measured value of the length of the supporting zones.



536 Prediction graph for space analysis of the supporting zone, according to Hixon and Oldfather, modified by Staley and Kerber
X-axis: Sum of mandibular incisor width measured on the dental cast and the total width of the first and second premolars measured on the periapical film. (Unilateral measurement; either the right or left side of the mandible is analyzed).

Y-axis: Predicted total width of permanent mandibular canine and first and second premolars.

The formula for calculation of the regression equation is as follows:
$\Sigma\, 3 + 4 + 5 = ([\Sigma\, 1 + 2 + X4 + X5] \times 0.7158) + 2.1267$
(X = measurements from radiograph)

Space Analysis in the Permanent Dentition

For patients with malalignment of teeth resulting from lack of space, it is important to determine from the study casts the amount of crowding in the maxillary and mandibular arches. The purpose is to determine the difference between space available and space required for tooth alignment. This means that two measurements are required in each arch for intramaxillary analysis of space requirement:
1) calculation of space required and
2) calculation of space available.
The analysis can be carried out by two methods:

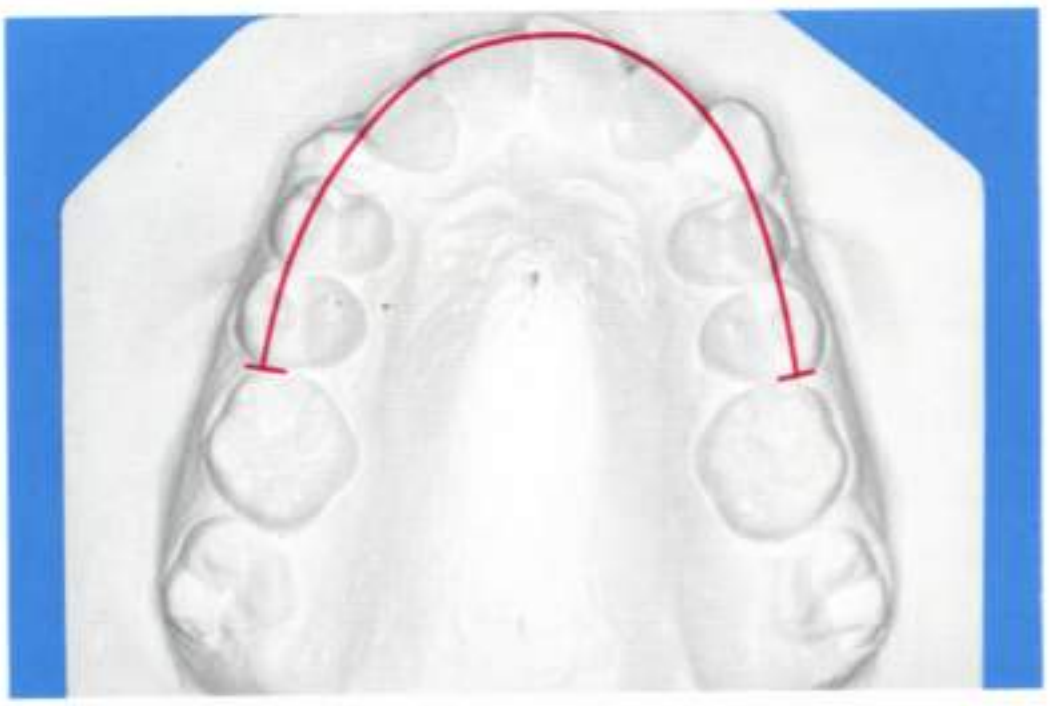
The Nance Analysis (Figs. 537–539)
The steps are as follows:
1) Recording the mesiodistal width of each tooth mesial to the first permanent molar. The sum total of the width corresponds to the necessary space required (ideal dental arch length).
2) Recording the actual arch length using a soft wire. This is contoured to the individual arch shape and placed on the occlusal surfaces over the contact points of the posterior teeth and the incisal edges of the anteriors. The distance between the mesial con-

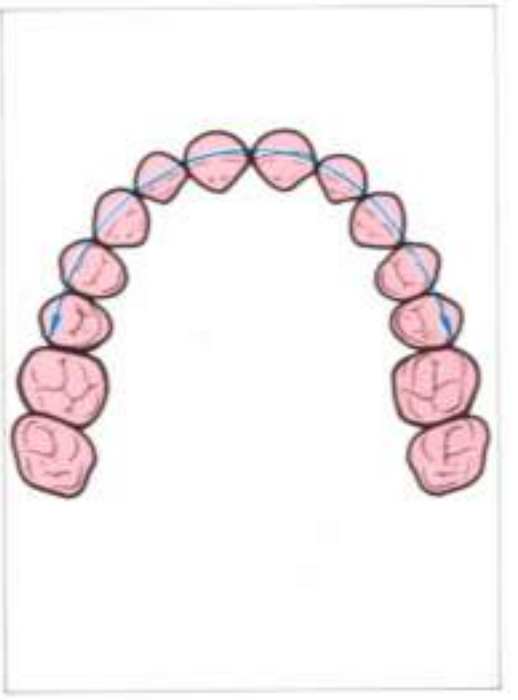
Recording space available in the permanent dentition, according to Nance

537 Measurement of the maxillary arch
The actual arch length is measured with the aid of a soft wire.

This is contoured to the individual arch form. In the posterior region it crosses the contact points and anteriorly it follows the incisal edges.

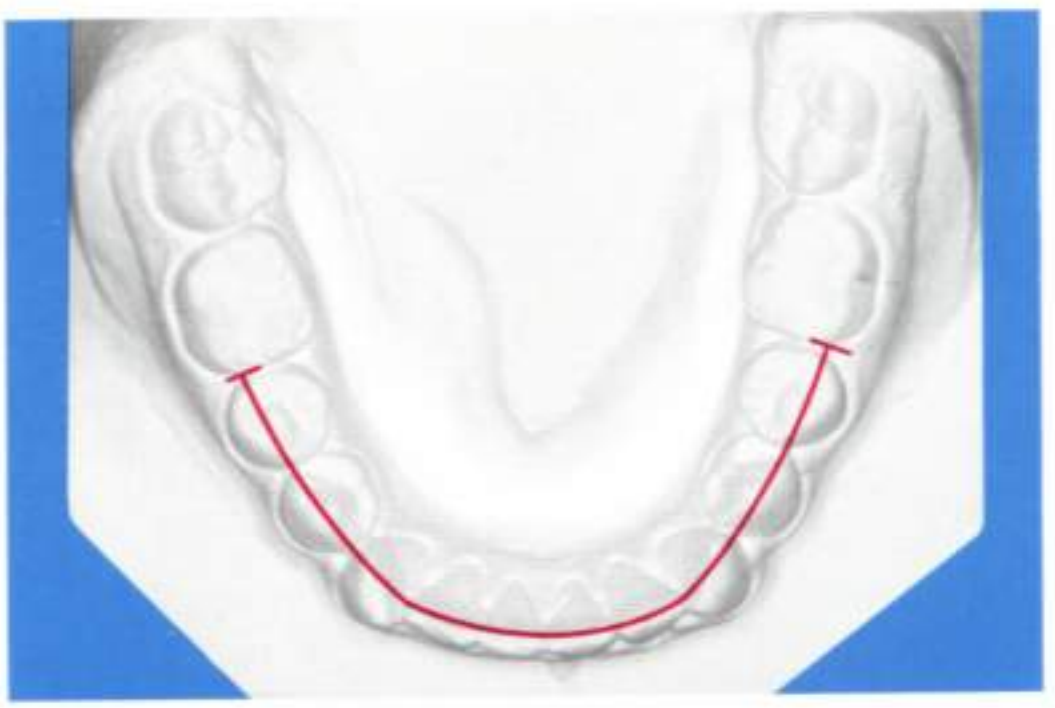
The actual arch length is obtained by measuring the arch perimeter mesial to the first permanent molars.

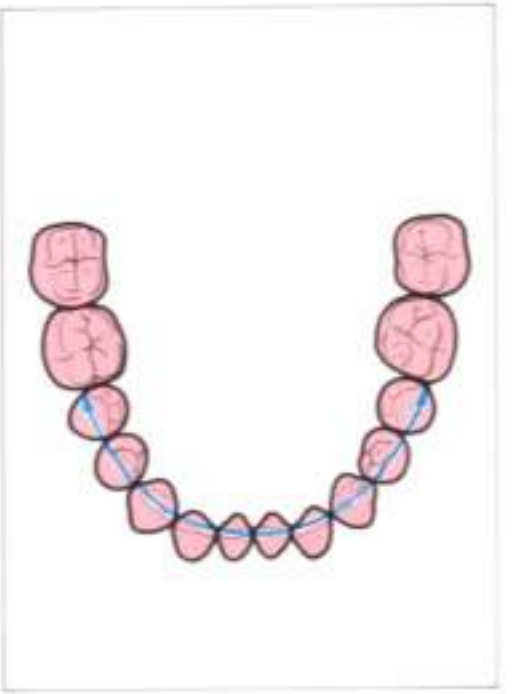




538 Measurement of the mandibular arch
Determination of the actual arch length is carried out in the same way as for the maxillary arch.

Right: Schematic illustration of the measurement.





539 Calculation of space required using the Nance analysis
Recording the measurements for the maxillary and mandibular arch from Figs. 537, 538 onto the chart and determining the difference between space required and space available.

Max:	Tooth	15	14	13	12	11	21	22	23	24	25
	Tooth width	7.5	8	7.5	7	8.5	9	7	7.5	7.5	7.5
	Space required					77 mm					
	Space available					70 mm					
	Difference					–7 mm					

Mand:	Tooth	45	44	43	42	41	31	32	33	34	35
	Tooth width	7	7	6	5	5	5	5	6	7	7
	Space required					60 mm					
	Space available					62 mm					
	Difference					+2 mm					

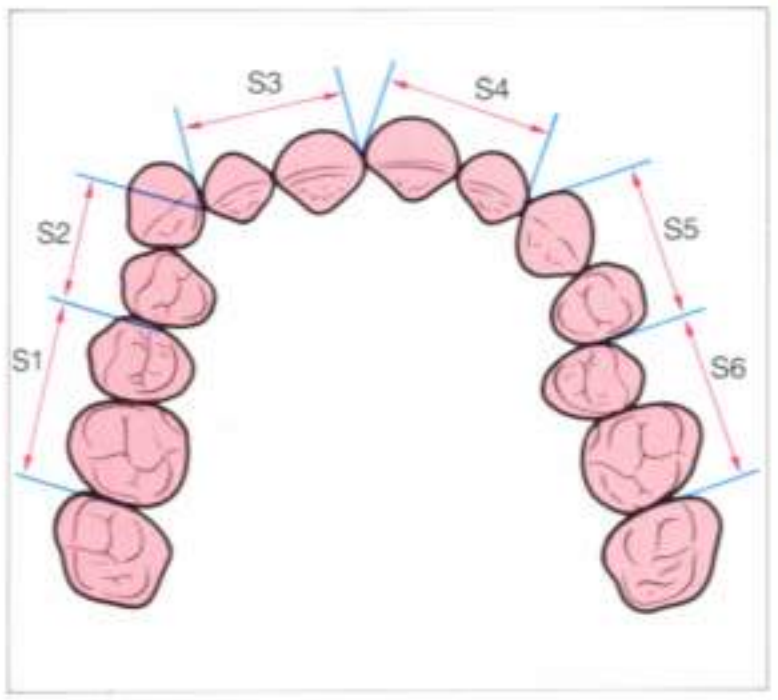
tact points of the first permanent molars – recorded from the straightened wire – is the amount of space available in the dental arch (actual arch length).

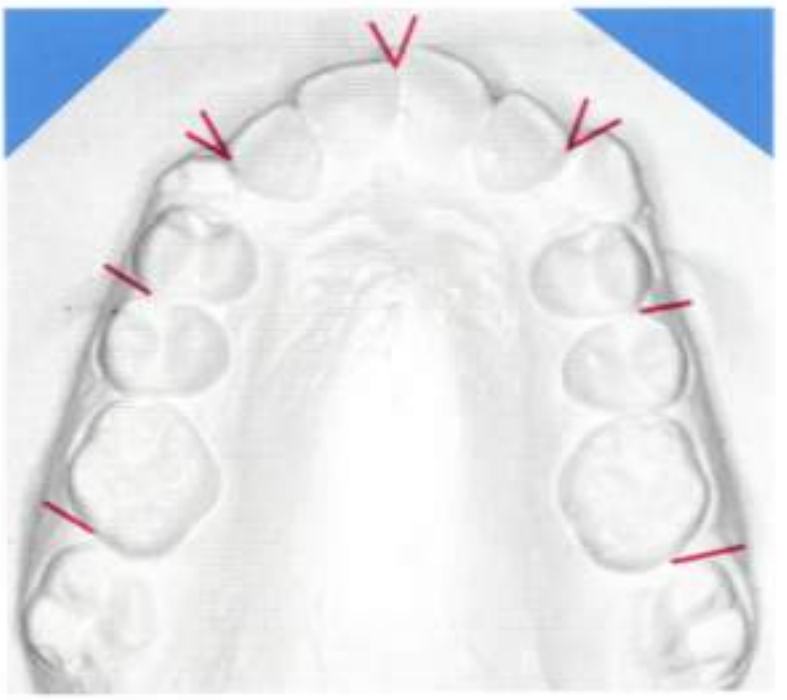
3) The assessment of space relationship is the result of the difference between the ideal and actual arch length (negative value = space deficiency, positive value = space excess) (Fig. 539).

The Lundström Segmental Analysis (Figs. 540–542)

The segmental analysis involves an indirect assessment of the dental arch perimeter, which can be carried out in the following way:

1) Division of the dental arch into six straight line segments of two teeth per segment, including the first permanent molars (Fig. 540).
2) Recording the mesiodistal width of the twelve teeth.
3) Summing the individual tooth width of each segment.
4) Recording the available mesiodistal space on the study cast separately for each segment.
5) The sum of the difference between ideal and actual length of each segment expresses the space relationship (Fig. 542).



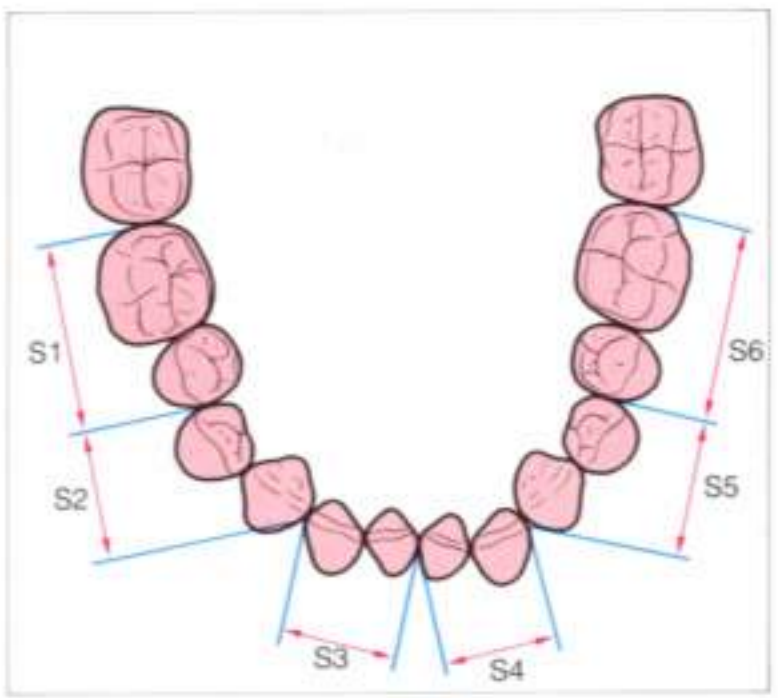


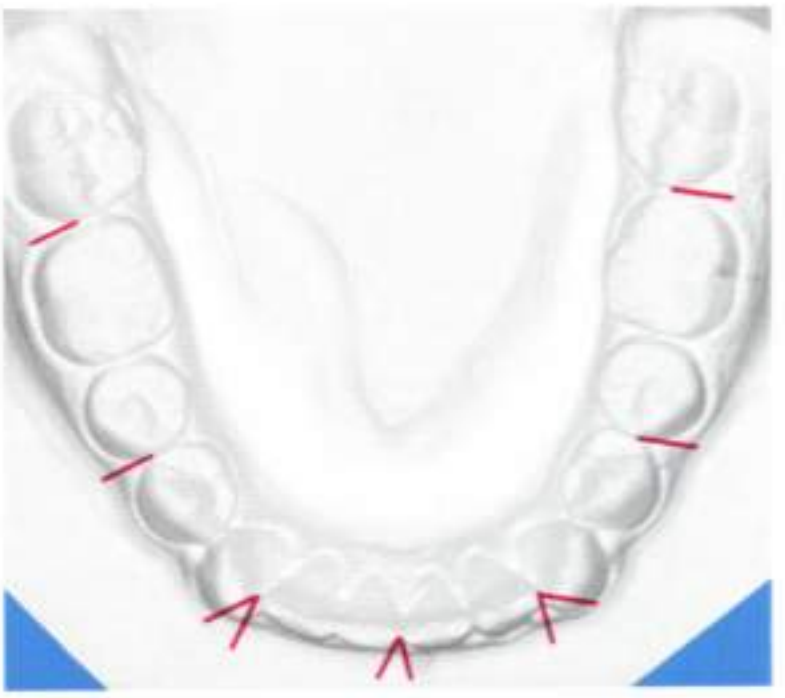
Determination of space available in the permanent dentition, according to Lundström

540 Segmental division of the maxillary arch

Schematic illustration and study cast showing the method of analysis for calculating the actual arch length in the permanent dentition (*Baugut*, 1983).

In this analysis, the measurement includes the first permanent molar.





541 Segmental division of the mandibular arch

Segmental division for the Lundström analysis to dermine the amount of space required in the permanent dentition is identical in the upper and lower arch.

Tooth	16	15	14	13	12	11	21	22	23	24	25	26
Tooth width	11	7.5	8	7.5	7	8.5	9	7	7.5	7.5	7.5	11
Segment	S1		S2		S3		S4		S5		S6	
Space required	18.5		15.5		15.5		16		15		18.5	
Space available	20.5		10.5		15		15.5		12.5		20	
Difference	+2.0		–5.0		–0.5		–0.5		–2.5		+1.5	
Discrepancy	–5 mm											

542 Calculation of space required using the segmental analysis of Lundström

Recording the individual measurements for analysis of space required in the upper arch from Fig. 540.

Discrepancy Calculation

Limiting the assessment of space relationships to the analysis of study casts is insufficient in itself. The difference between space required and the amount of space available for alignment of the teeth is determined by two different parameters:

1) Amount of dental crowding
2) Anteroposterior position of the incisors in relation to the facial skeleton.

Comprehensive space analysis must therefore consist of a combined analysis including measurements from the cephalogram and study casts. The steps in this overall discrepancy calculation in upper and lower arches are:

1. Determination of dental discrepancy

On the study cast are calculated: a) the difference between the actual and ideal dental arch length (p. 220) and b) the amount of curve of Spee separately on the left and right side (p. 227). (To level the curve of Spee by 1 mm requires 1 mm of arch length).

The sum of the measurements of a) and b) is known as the dental discrepancy (DD).

543 Discrepancy calculation
Upper left: The dental discrepancy (DD) combines the difference between the actual and ideal arch length and the degree of deviation of the curve of Spee from the standard. The latter is determined by the sum total of the individual measurements for the left and right side.

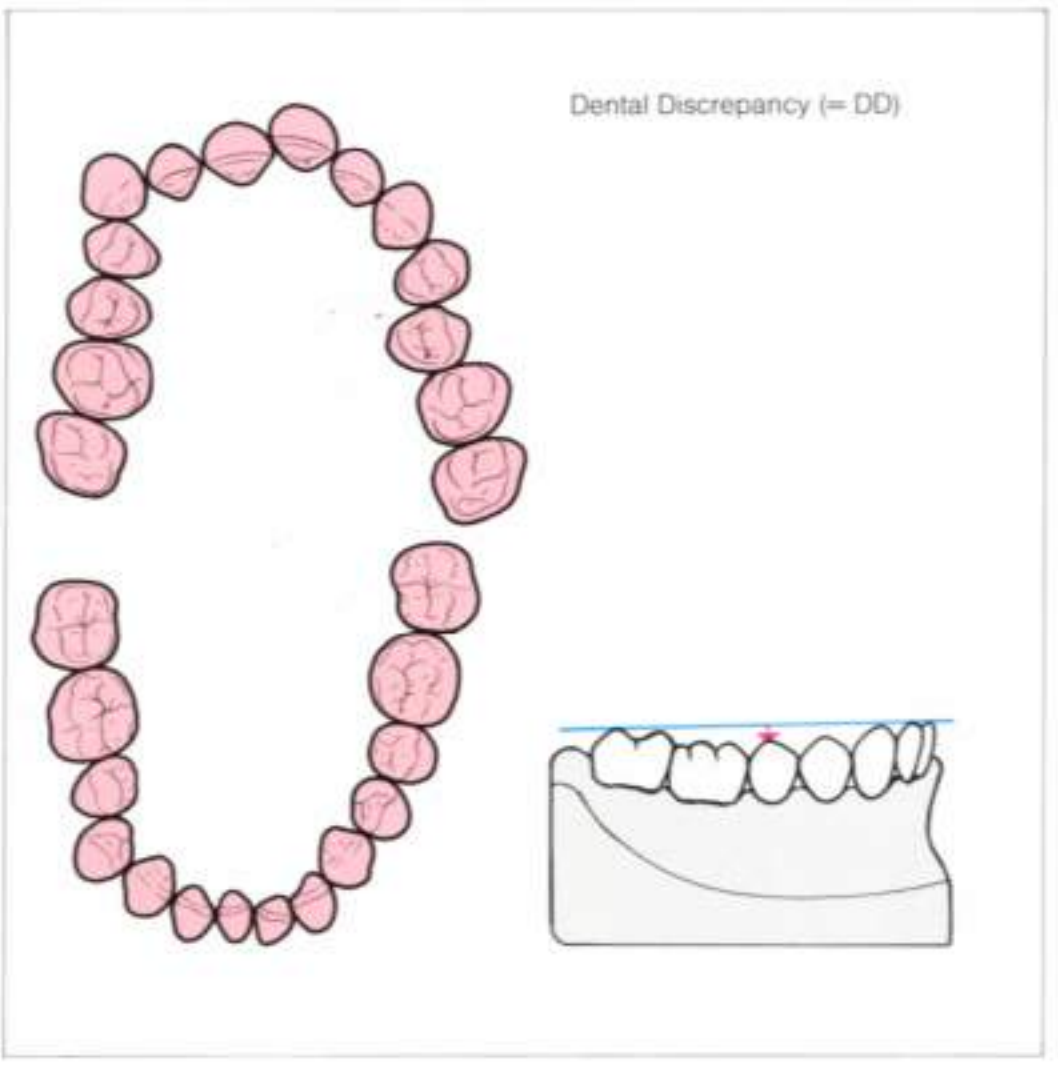
Upper right: The sagittal discrepancy (SD) represents the deviation in the relationships between the upper and lower incisal edges to the N-Pog-line (standard value in the maxillary arch +2 to +4 mm, standard value in the mandibular arch –2 to +2 mm).

If the incisors are too far labial with respect to the standard value, in order to achieve a correct axial inclination, dental arch length is required in a 1:1 relation.

In the opposite case, where the incisal edges lie too far posteriorly (lingual), an increase in dental arch length is gained to the same degree.

Below: To calculate the total discrepancy (sum total of the discrepancies from the study cast and roentgenocephalometric analyses) the bilateral measurement of dental discrepancy (DD) and of the unilateral measurement of sagittal discrepancy (SD) must be reduced to a common denominator. To calculate the total discrepancy for one arch side the value of the dental discrepancy is divided by two and then this figure added to the value of the sagittal discrepancy.

The analysis can be performed in the permanent dentition as well as in the mixed dentition. It differs only in the divergent calculation of actual and ideal arch length. However, when calculating the sagittal discrepancay in adolescents, attention mus be paid to the expected growth-related changes in position of the N-Pog-line.



Mandibular discrepancy calculation

Space available:		mm		
Space required:		mm	DD =	mm
Curve of Spee:		mm		
Distance from lower incisors to N-Pog:		mm	SD =	mm
Discrepancy per arch side	$\left(\frac{DD}{2} + SD\right)$:	mm	Total =	mm

Maxillary discrepancy calculation

Space available:		mm		
Space required:		mm	DD =	mm
Curve of Spee:		mm		
Distance from upper incisors to N-Pog:		mm	SD =	mm
Discrepancy per arch side	$\left(\frac{DD}{2} + SD\right)$:	mm	Total =	mm

2. Determination of sagittal discrepancy

The distance of the incisal edge of the central incisors to the N-Pog-line is measured on the lateral cephalogram. The degree to which incisor position varies from the standard value represents the sagittal discrepancy (SD). A forward position of the incisors signifies a need of dental arch length, retroposition signifies an increase in dental arch length (1 mm change of incisor position in the lateral cephalogram = 1 mm arch length).

3. Determination of total discrepancy

Total discrepancy (TD) is the sum of the dental and sagittal discrepancy and – since the measurement which is for both sides of the dental arch on the study cast but only on one side on the radiograph – is calculated as follows:

$$\text{TD per arch side} = \text{SD} + 1/2\ \text{DD}$$

The amount of the total discrepancy is a significant parameter for deciding whether extractions are necessary.

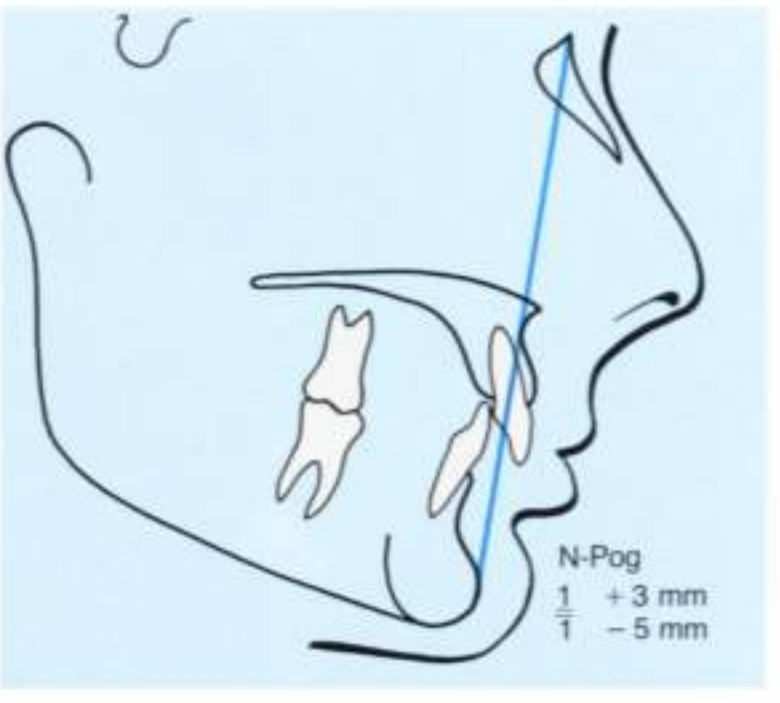
If the discrepancy calculation is carried out in the mixed dentition, growth-related changes in the position of the N-Pog-line must be taken into account, most of all the type of mandibular rotation (p. 192).

Discrepancy calculation
– 1st case example –

544 Dental discrepancy

Left: In the upper arch the actual arch length is 8 mm shorter than the ideal arch length (measured from the mesial contact point of the first molar to the mesial of the opposite molar).

Right: In the lower arch, available space is 8 mm less than space required. The curve of Spee is excessive by 2 mm on each side.



545 Sagittal discrepancy

The value of the distance of the upper central incisors (= + 3 mm) equals the standard value.

The incisal edge of the most labially placed lower central incisor is 5 mm too far posterior.

Taking the average standard value (–2 to +2 mm) as a baseline for discrepancy calculation, one gains 5 mm in arch length on each side if the incisal edge is placed on the N-Pog-line.

Discrepancy calculation

Upper jaw			**Lower jaw**		
Dental discrepancy			Dental discrepancy		
Space available	:	59 mm	Space available	:	50 mm
Space required	:	67 mm	Space required	:	58 mm
Curve of Spee	:	0 mm	Curve of Spee	:	–4 mm
Sum DD	:	–8 mm	Sum DD	:	–12 mm
Sagittal discrepancy			Sagittal discrepancy		
$\underline{1}$-N-Pog	:	+3 mm	$\overline{1}$-N-Pog	:	–5 mm
SD	:	0 mm	SD	:	+5 mm
Total discrepancy/ Arch side	:	–4 mm	Total discrepancy/ Arch side	:	–1 mm

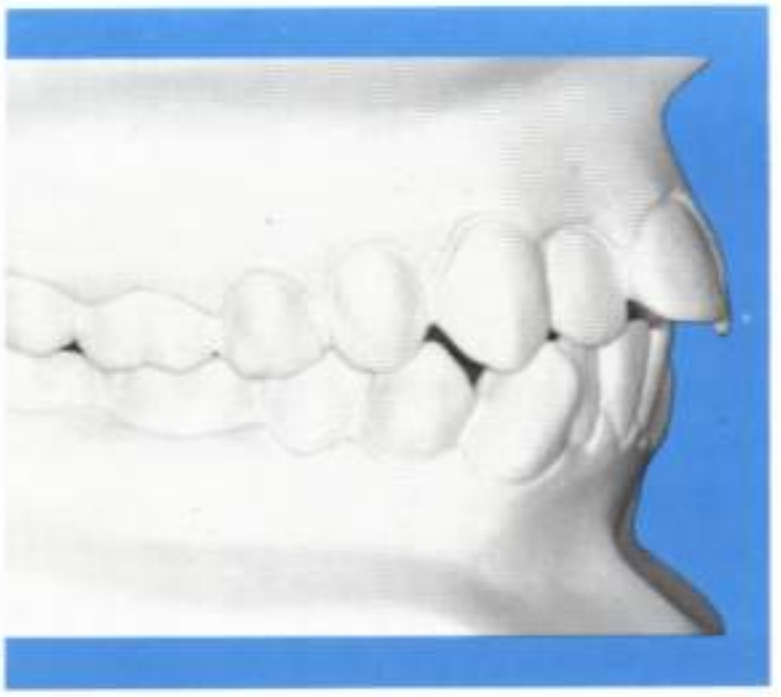
546 Calculation of total discrepancy

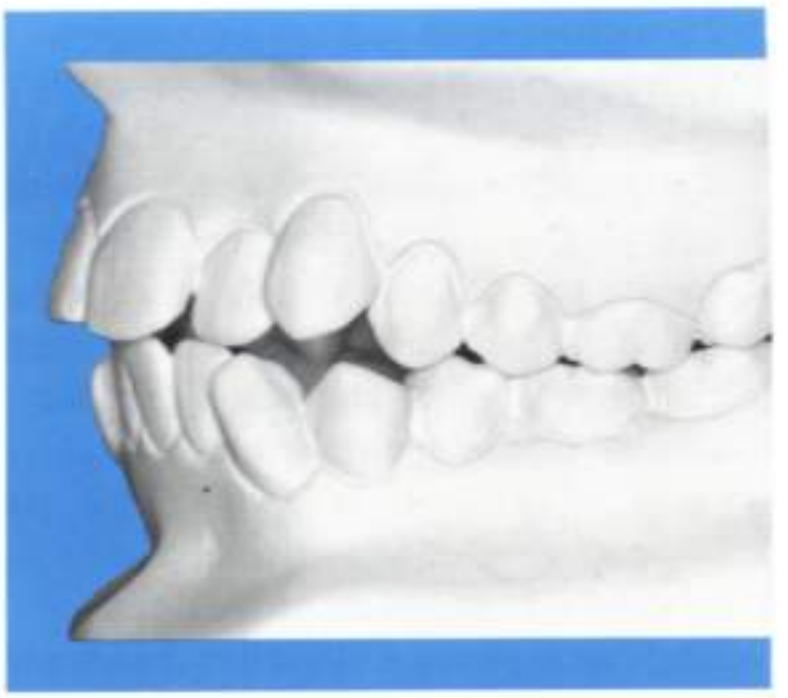
The separate measurements of dental and sagittal discrepancies are recorded on the chart.

After calculating the total discrepancy, lack of maxillary arch space is clearly more marked than in the mandible, as in the lower arch the dental discrepancy is compensated by the more favorable initial position of the lower incisors to the N-Pog-line.

Discrepancy calculation
– 2nd case example –

547 Occlusal findings
Class I relationship with minimal anterior overbite. The anterior teeth are malaligned due to lack of space and the upper central incisors are labially inclined.





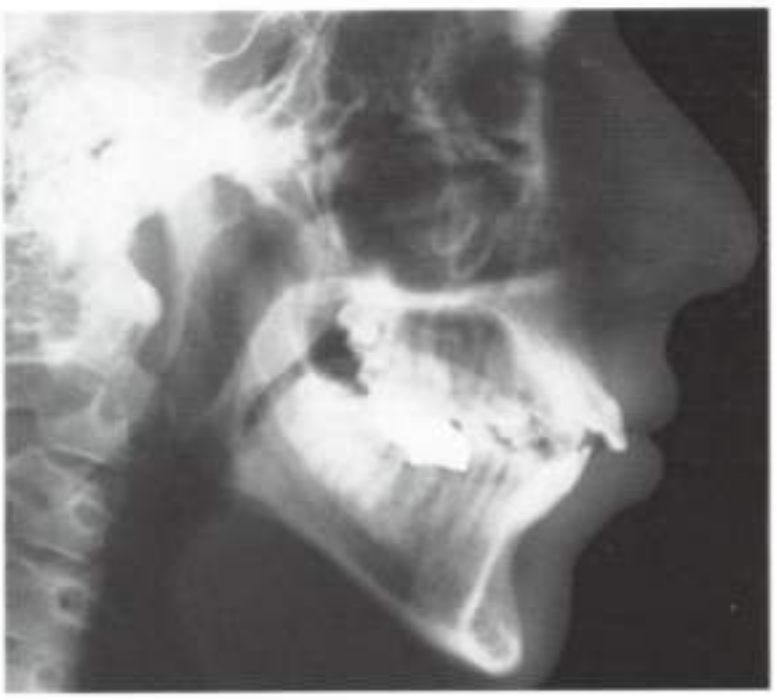
548 Dental discrepancy
Oclusal view of the upper and lower dental arches.

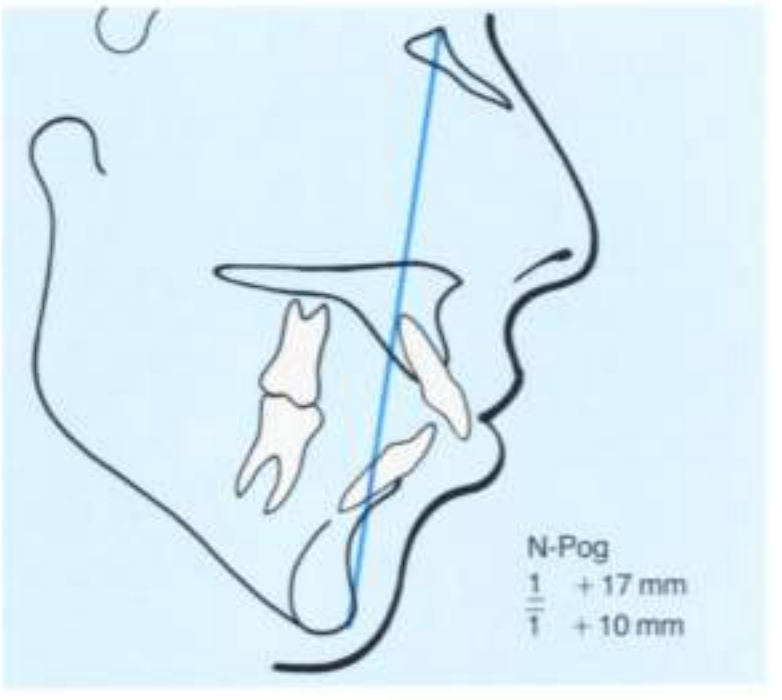
In the maxillary arch, the actual arch length is 7 mm too short. In the mandible, the amount of space required is 5 mm.

The curve of Spee shows no marked abnormality.

549 Sagittal discrepancy
Considering the upper limit of the standard value (maxillary arch +4 mm, mandibular arch +2 mm), 13 mm of arch length is required in the maxillary arch in order to correctly position the incisal edges to the N-Pog-line.

Mandibular sagittal discrepancy amounts to –8 mm.





550 Calculation of total discrepancy
The individual measurements for dental and sagittal discrepancy are shown in this chart.

In order to achieve ideal occlusal relationships, 16.5 mm are required per maxillary arch side, and 10.5 mm per mandibular arch side.

The discrepancy signifies that a compromise result is only possible if purely orthodontic measures are performed, even in combination with extraction therapy.

Discrepancy calculation

Maxillary arch		Mandibular arch	
Dental discrepancy		Dental discrepancy	
Space available :	69 mm	Space available :	65 mm
Space required :	76 mm	Space required :	70 mm
Curve of Spee :	0 mm	Curve of Spee :	0 mm
Sum DD :	–7 mm	Sum DD :	–5 mm
Sagittal discrepancy		Sagittal discrepancy	
1-N-Pog :	+17 mm	1-N-Pog :	+10 mm
SD :	–13 mm	SD :	–8 mm
Total discrepancy/ Arch side :	–16.5 mm	Total discrepancy/ Arch side :	–10.5 mm

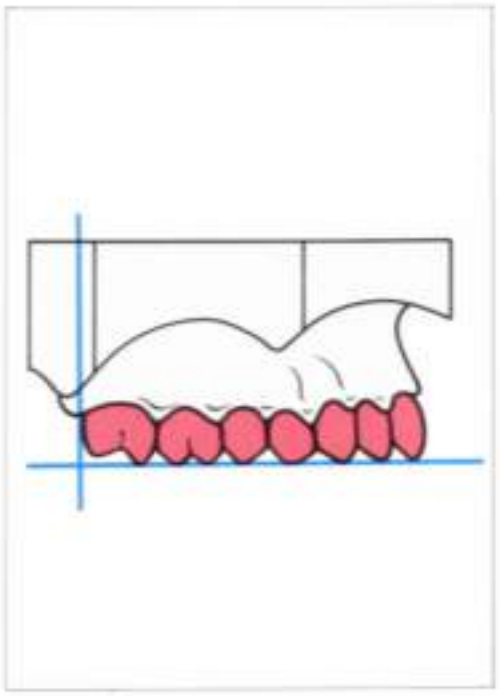
Analysis in the Vertical Plane

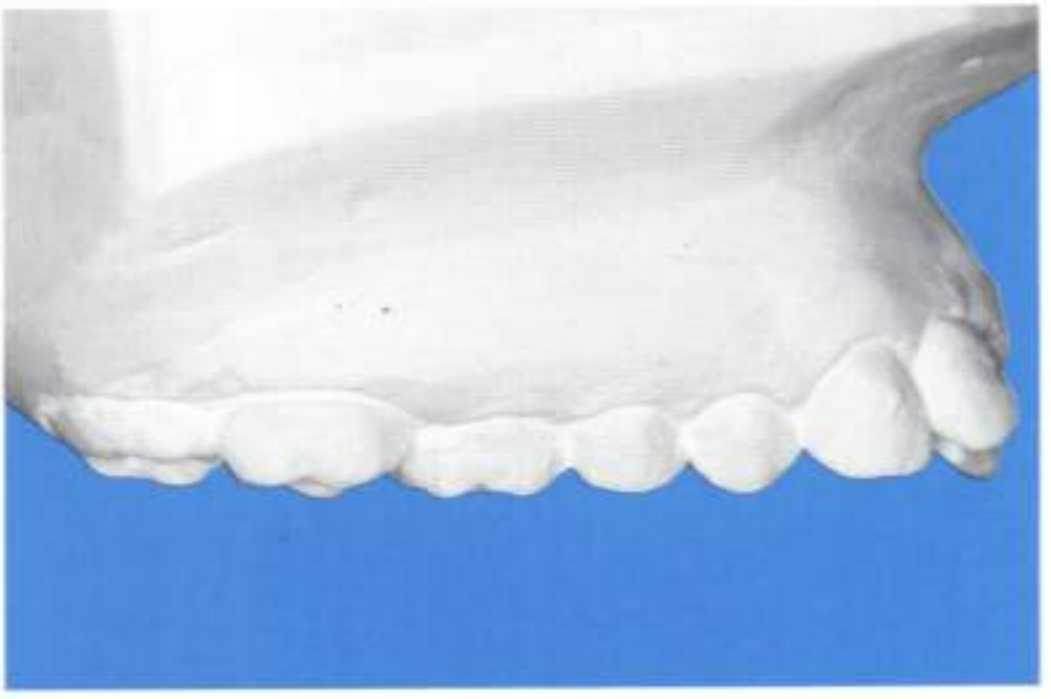
The degree of malposition of individual teeth and groups of teeth in the vertical plane is measured in relationship to the *occlusal plane*, and is described as follows:

Supraversion = overeruption in relation to the occlusal plane
Infraversion = insufficient eruption in relation to the occlusal plane

The occlusal plane is a fictitious, constructed plane which does not actually exist, as the occlusal surfaces of the teeth do not lie on one plane. Therefore, precise measurements cannot be made and it only serves as a point of reference when describing vertical anomalies.

Examination in the vertical plane also involves analysis of the sagittal compensating curve *(curve of Spee)*. This can be steep, flat, or reverse. A steep curve of Spee is often combined with crowding, whereas a flat curve allows a good occlusion. Overeruption of incisors in a deep bite case can be combined with a pronounced transverse compensating curve.

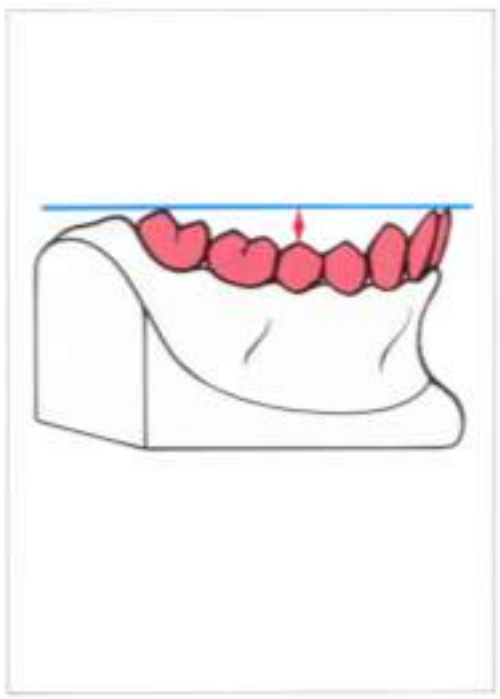




551 Vertical plane – normal incisor position
In a correct vertical relationship the incisal edges contact the occlusal plane.

Left: Schematic illustration showing the occlusal plane and the tuberosity plane perpendicular to it. The occlusal plane is defined by the tangent which runs through the tips of the mesiobuccal cusps of the first molars and the buccal cusps of the premolars.

552 Supraversion of the anterior teeth
Supraversion of the incisors with overeruption in relationship to the occlusal plane.



553 Measurement of the curve of Spee
The depth of the curve of Spee is defined as the distance from the vertex of the curvature to the side of a plastic template placed over the lower arch. The template touches anteriorly the incisal edges and posteriorly the distal-most molar cusps. The measurement is carried out separately on both the left and right sides of the dental arch.

Left: Diagram illustrating the measurement.

Bolton Analysis

The Bolton analysis (Bolton, 1958) determines the ratio of the mesiodistal widths of the maxillary versus the mandibular teeth (i.e., tooth size discrepancy). In the analysis of the *overall ratio* the relationship of the 12 mandibular teeth to the 12 maxillary teeth is assessed (second and third molars are excluded). On account of the importance for the canine relations as well as for overbite and overjet relationships, a further analysis is performed to evaluate the ratio between the six upper and lower anterior teeth *(anterior ratio)*.

For this analysis it is postulated that the relatively smaller tooth material is the correct one. The tooth width that is perfectly related to this size in the opposite arch is found in the correlation table of standard values.

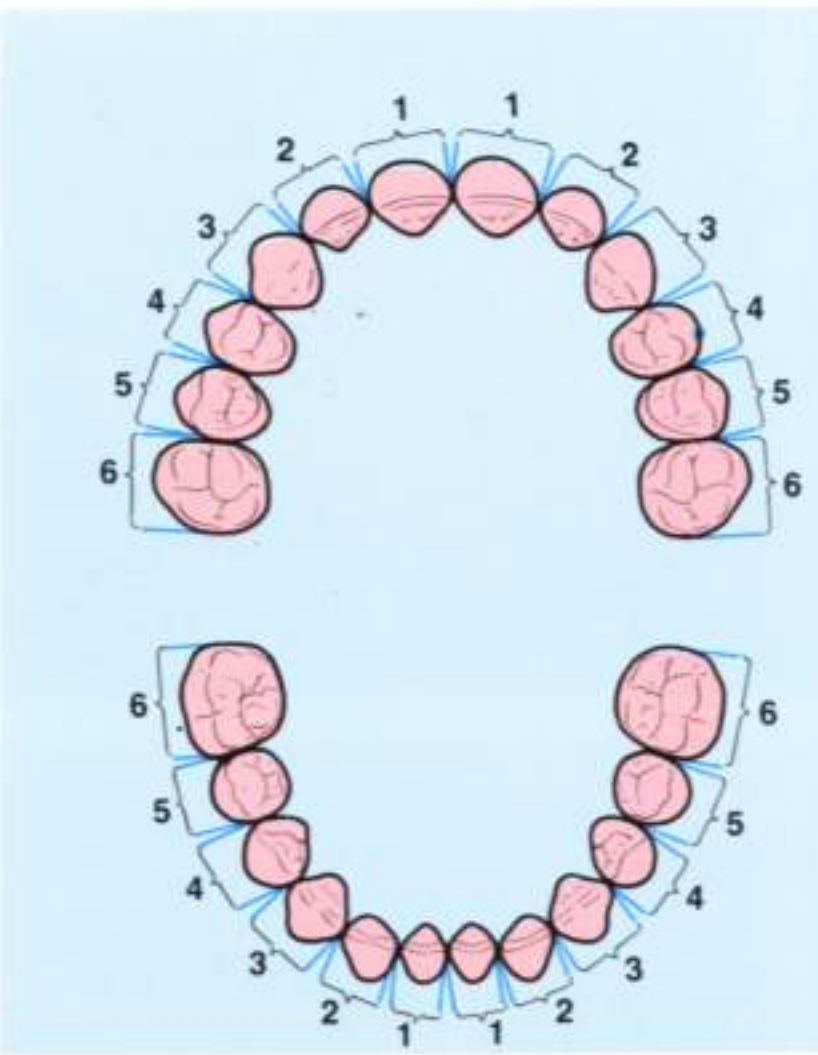
Only index deviations of more than two standard deviations are of clinical relevance. In normal occlusal relationships and good incisor position tooth size discrepancies are often the cause of rotations, space formations, crowding and incorrect intercuspation. Disharmony between the width of upper and lower teeth can be improved by: 1) extractions, 2) interdental stripping, 3) in extreme cases, by increasing the mesiodistal tooth size.

554 Index of overall ratio
Formula to determine the intermaxillary mesiodistal congruence of overall tooth widths, including the first permanent molars.

If the calculated ratio is greater than 91.3%, the mandibular teeth are too wide compared to the maxillary teeth. If the ratio is reduced, the maxillary teeth are relatively too large.

For analysis of dental material the 12 upper and 12 lower teeth are measured at their widest mesiodistal points. The method is confined to the permanent dentition.

The main cause of tooth width discrepancy is a right-left asymmetry of mesiodistal tooth size.

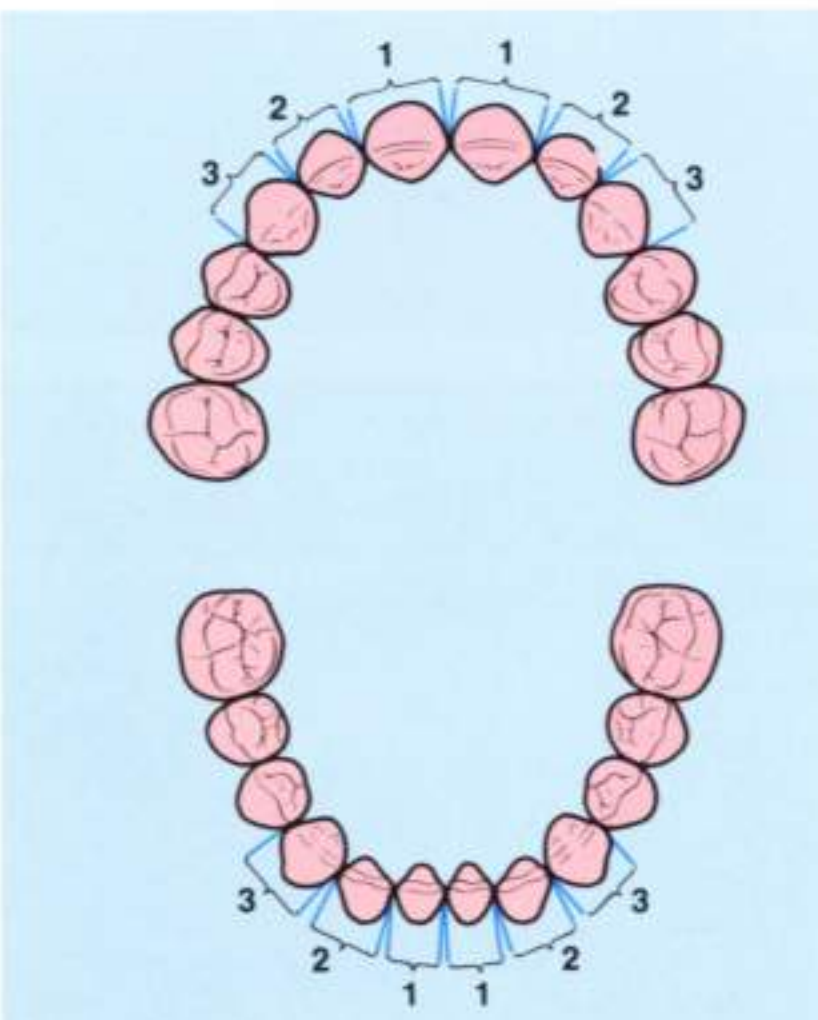


Overall ratio:

$$\frac{\text{Sum mand}_{12}\ \text{(m-d)}}{\text{Sum max}_{12}\ \text{(m-d)}} \times 100 = 91.3\% \pm 0.26$$

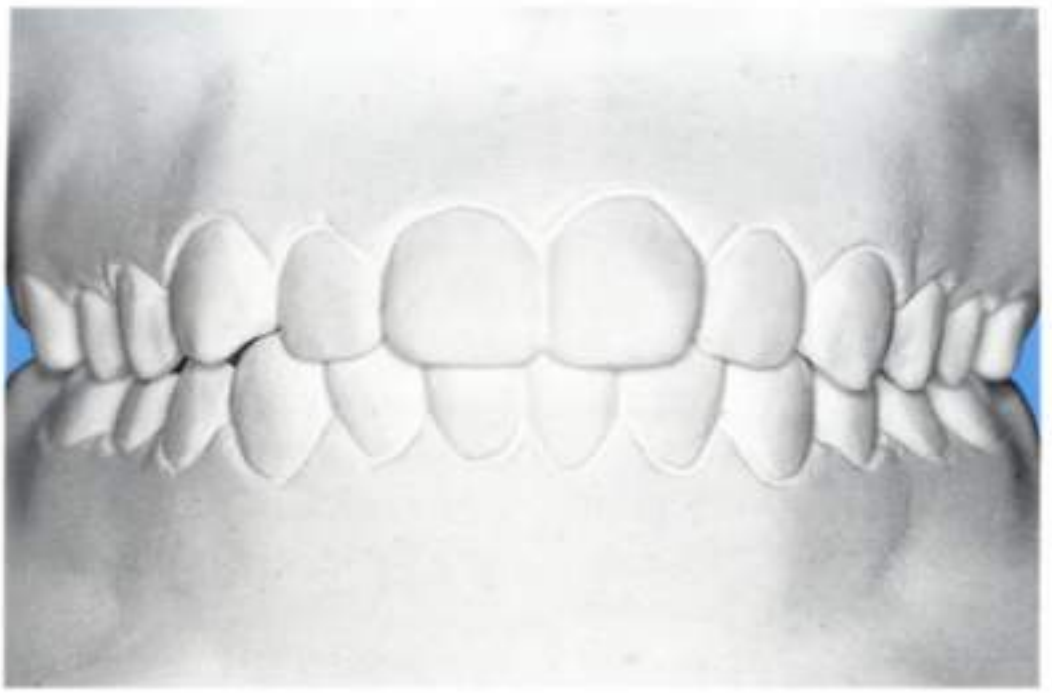
555 Index of anterior ratio
Formula to determine the intermaxillary tooth width congruence in the anterior region. If the ratio is greater than 77.2% the total width of the lower six anterior teeth is relatively too large. If the index value is reduced, the discrepancy is due to an excess in maxillary tooth material.

The relevance of the anterior index value is greatly reduced in the following situations:
- severe labioversion of lower incisors
- abnormally large labiolingual diameter of the incisal edges.



Anterior ratio:

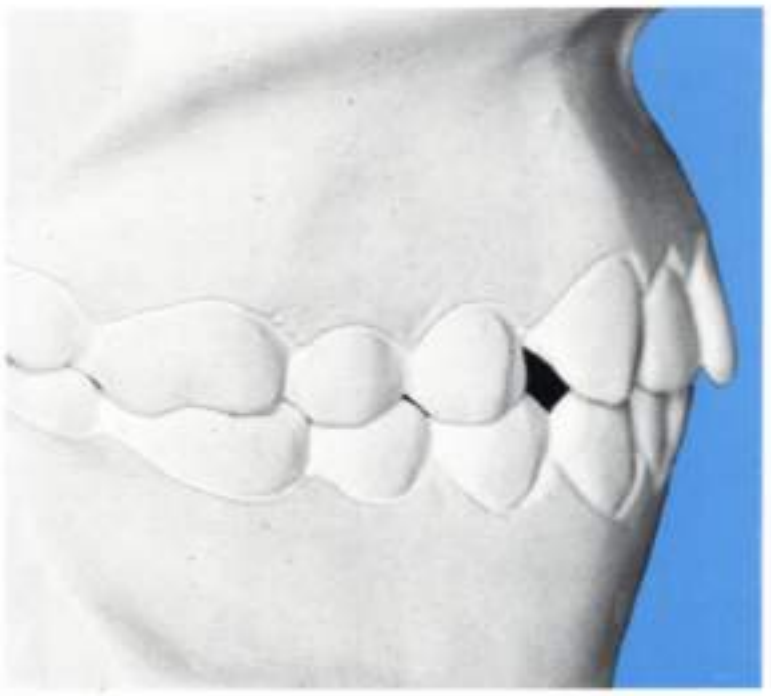
$$\frac{\text{Sum mand}_{6}\ \text{(m-d)}}{\text{Sum max}_{6}\ \text{(m-d)}} \times 100 = 77.2\% \pm 0.22$$

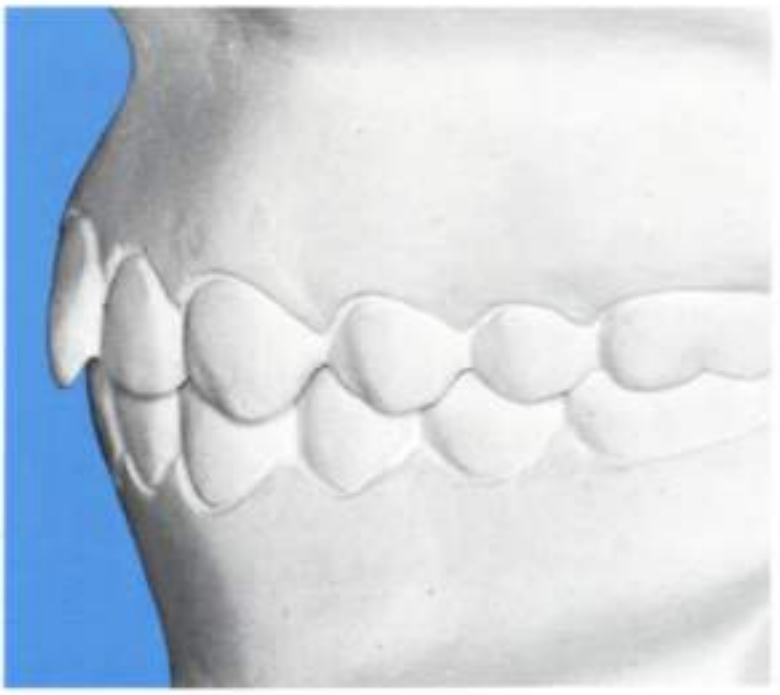


Discrepancy in the anterior ratio
– case example –

556 Anterior view of the study casts
Maxillary and mandibular anterior arches with tight contacts; in the lower dental arch mild incisor crowding and midline deviation to the right.

The overall ratio is 91.9%, the anterior ratio is 82%; i.e. the tooth size discrepancy is localized in the anterior region. The summed width of the six mandibular teeth is 2.4 mm relatively enlarged.





557 Occlusal relationships
Bilateral neutroclusion of first permanent molars with slight distoclusion in the canine region.

In addition to malalignment of lower anterior teeth, the anterior tooth size discrepancy prevents correct intercuspation of the canines.

Excessive Mesiodistal Tooth Material

in the maxillary arch

- increased overbite
- increased overjet
- crowding in the maxillary arch
- spacing in the mandibular arch
- linguoversion of upper incisors
- labioversion of lower incisors

in the mandibular arch

- reduced overbite
- reduced overjet
- crowding in the mandibular arch
- spacing in the maxillary arch
- labioversion of upper incisors
- linguoversion of lower incisors

558 Intermaxillary tooth size discrepancy and malalignment of teeth
A disproportion between upper and lower tooth size has certain effects on tooth position and occlusion. The deviation depends on the localization of the excessive tooth material: maxillary or mandibular arch.

55a Disproportionate intermaxillary tooth size as a result of morphologic anomalies
Hypoplastic upper lateral incisors which markedly affect the ratio between upper and lower tooth width. In these extreme cases a decision must be made prior to treatment as to whether the disproportion can be corrected by interproximal enamel stripping of the opposing teeth or whether the discrepancy needs to be corrected by restoration of the hypoplastic teeth.

560 Ideal relationship of maxillary and mandibular tooth widths according to Bolton

Table of average values for the overall and anterior ratio (figures in mm)

After calculation of the Bolton ratio, the arch with the relatively smaller tooth material is determined and the actual figure corresponding to the arch tooth size located in the table. The ideal value for the size of the opposing teeth is read off from the accompanying column.

The difference between the actual value and the ideal value (according to the table) for the relatively enlarged tooth material represents in mm the amount of excess tooth size in this arch.

Overall ratio

max_{12}	:	$mand_{12}$	max_{12}	:	$mand_{12}$	max_{12}	:	$mand_{12}$
85		77.6	94		85.8	103		94.0
86		78.5	95		86.7	104		95.0
87		79.4	96		87.6	105		95.9
88		80.3	97		88.6	106		96.8
89		81.3	98		89.5	107		97.8
90		82.1	99		90.4	108		98.6
91		83.1	100		91.3	109		99.5
92		84.0	101		92.2	110		100.4
93		84.9	103		93.1			

Anterior ratio

max_6	:	$mand_6$	max_6	:	$mand_6$	max_6	:	$mand_6$
40.0		30.9	45.5		35.1	50.5		39.0
40.5		31.3	46.0		35.5	51.0		39.4
41.0		31.7	46.5		35.9	51.5		39.8
41.5		32.0	47.0		36.3	52.0		40.1
42.0		32.4	47.5		36.7	52.5		40.5
42.5		32.8	48.0		37.1	53.0		40.9
43.0		33.2	48.5		37.4	53.5		41.3
43.5		33.6	49.0		37.8	54.0		41.7
44.0		34.0	49.5		38.2	54.5		42.1
44.5		34.4	50.0		38.6	55.0		42.5
45.0		34.7						

561 Evaluation chart for the Bolton analysis

Mesiodistal tooth sizes:

R L

Overall ratio: $\frac{\text{Sum mand}_{12}\ \text{mm}}{\text{Sum max}_{12}\ \text{mm}} \times 100 =$ %

Anterior ratio: $\frac{\text{Sum mand}_6\ \text{mm}}{\text{Sum max}_6\ \text{mm}} \times 100 =$ %

Overall ratio > 91.3%

$\frac{\text{mm}}{\text{Actual mand}_{12}} - \frac{\text{mm}}{\text{Ideal mand}_{12}} = \frac{\text{mm}}{\text{Diff.}}$

Overall ratio < 91.3%

$\frac{\text{mm}}{\text{Actual max}_{12}} - \frac{\text{mm}}{\text{Ideal max}_{12}} = \frac{\text{mm}}{\text{Diff.}}$

Anterior ratio > 77.2%

$\frac{\text{mm}}{\text{Actual mand}_6} - \frac{\text{mm}}{\text{Ideal mand}_6} = \frac{\text{mm}}{\text{Diff.}}$

Anterior ratio < 77.2%

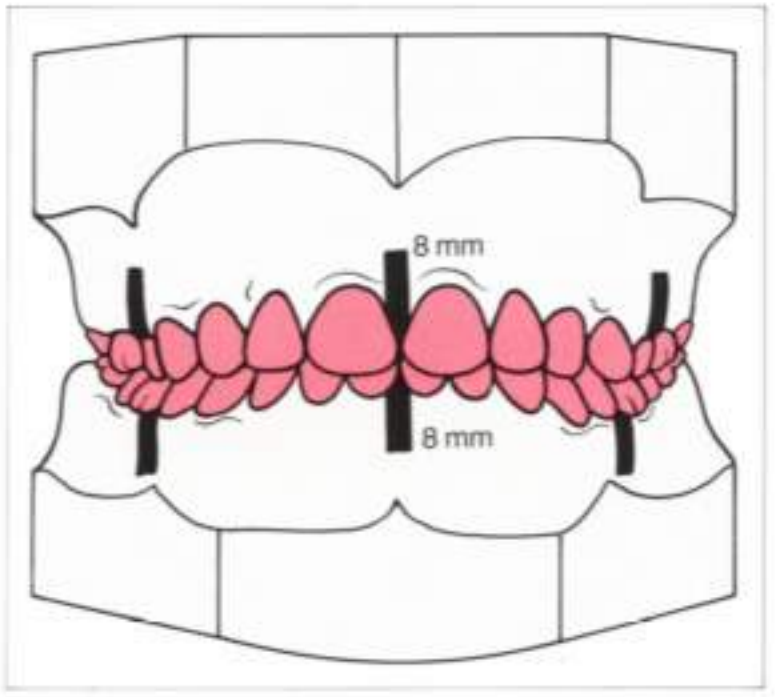
$\frac{\text{mm}}{\text{Actual max}_6} - \frac{\text{mm}}{\text{Ideal max}_6} = \frac{\text{mm}}{\text{Diff.}}$

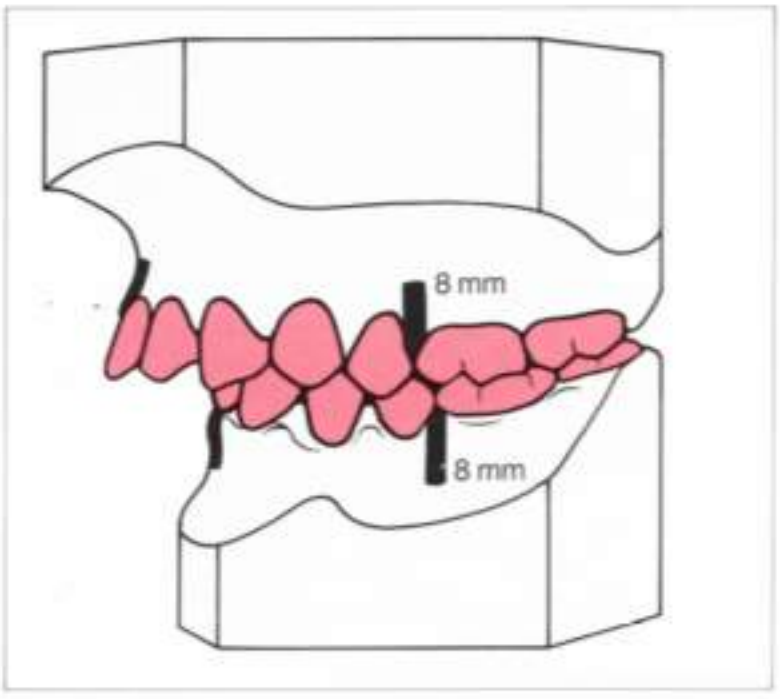
Analysis of the Apical Base, According to Rees

The relation between the overall extent of the apical base and the length of the dental arch is expressed metrically for the upper and lower jaws. The analysis is carried out as follows:

1) Erasing of the lip and cheek frena on the casts.
2) Construction of three perpendiculars to the occlusal plane (mesial to the first permanent molars and at the contact point of the central incisors). These lines are extended by 8–10 mm from the dental papilla toward the vestibular fold.
3) Measuring the distance from the mesial of the first permanent molar on one side to that on the other side through the tips of the vertical lines with the aid of a piece of thin adhesive tape.
4) Determining dental arch length by measuring the arch perimeter mesial to the first permanent molars using a piece of brass wire.

The individual values are compared to one another within the same arch and to the opposing arch (Fig. 564) and the calculated figures compared to the standards according to Rees (1953). This method is confined to the permanent dentition.

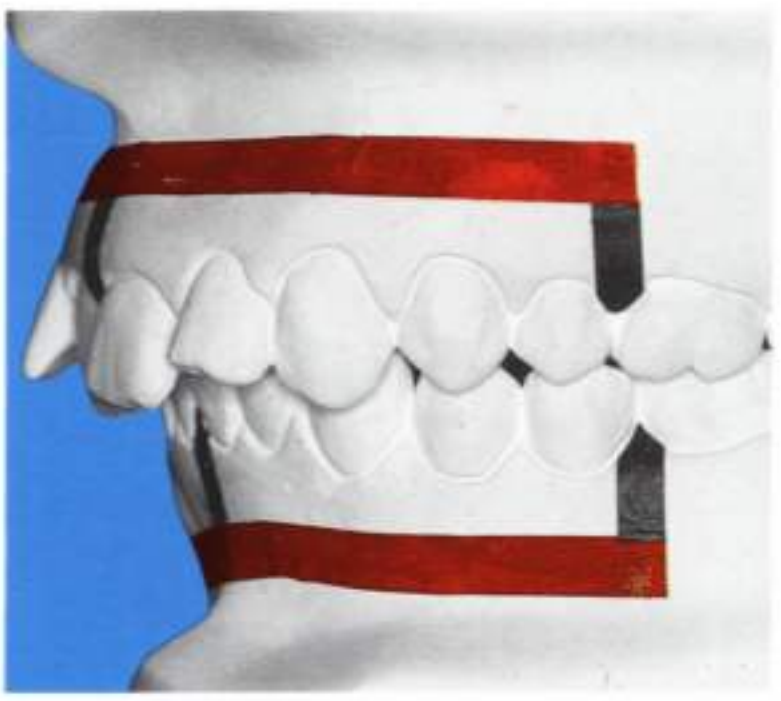




Assessing the size of the apical base

562 Marking the reference points
Left: The incisal reference point is marked on a vertical line which extends from the occlusal plane through the contact point of the central incisors toward the vestibular fold, 8 mm from the gingival margin.

Right: Using the same criteria, the molar point is marked bilaterally through the mesial contact point of the first molar, 8 mm from the gingival margin on the alveolar process.



563 Measuring the apical base
Measurement of the apical base is carried out using a thin adhesive tape, extending from the distal reference point on one side through the incisal reference point to the distal marking on the other side.

The adhesive tape is then removed from the study cast and its length measured.

Measurement			Ideal values (Rees)		
Maxillary apical base	—	Maxillary dental arch:	+1.5	—	+ 5.0 mm
Mandibular apical base	—	Mandibular dental arch:	+2.0	—	+ 7.0 mm
Maxillary apical base	—	Mandibular apical base:	+3.0	—	+ 9.5 mm
Maxillary dental arch	—	Mandibular dental arch:	+5.0	—	+10.0 mm

564 Ideal relations according to Ress
For these measurements the second parameter is subtracted from the first. The arrangement of comparisons is made in such a way that in the normal case the first measurement is larger than the second.

In borderline cases the analysis provides information for treatment planning (in particular extraction or nonextraction).

Examination of Occlusion

This three-dimensional analysis estimates the intermaxillary relationship between the upper and lower dental arches in habitual occlusion.

Transverse Malocclusions
- *Anterior:* Anterior cross-bite, skeletal mandibular midline shift (displacement of the entire mandible in relation to the facial midsagittal plane)
- *Posterior:* posterior cross-bite (uni-, bilateral), non-occlusion (buccal, lingual)

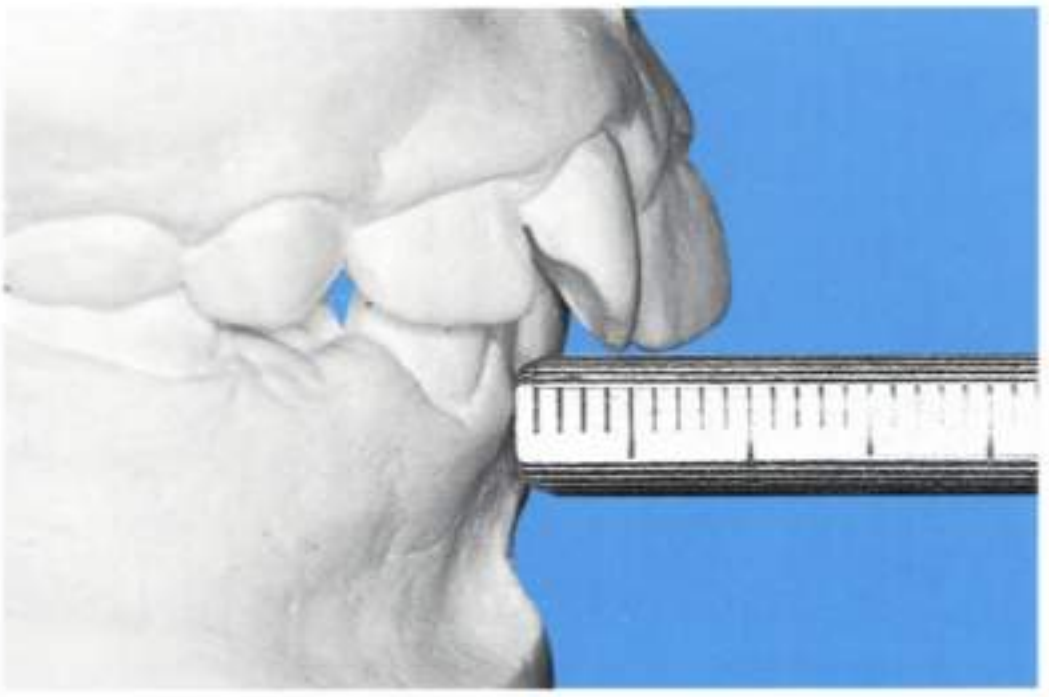
Anteroposterior Malocclusions
- *Anterior:* increased overjet, negative overjet
- *Posterior:* distoclusion, mesioclusion

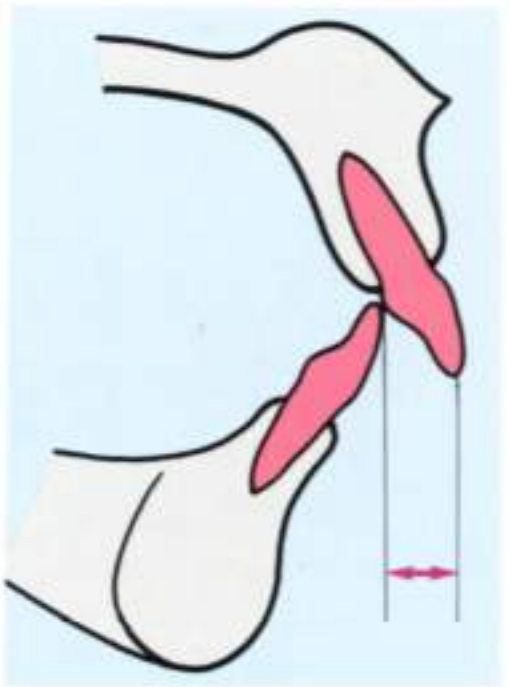
Vertical Malocclusions
Unsupported overbite, deep bite (dentally/gingivally supported), open bite (anterior, lateral, complex).

When examining the occlusion, a distinction has to be made between the occlusal relations and the maxillo-

565 Measuring the overjet
Determination of the overjet with a graduated ruler. (For clarity, the ruler markings are visible)

Right: The overjet is defined as the distance between the labial surface of the lower central incisor and the upper incisal edge. The measurement is performed parallel to the occlusal plane.

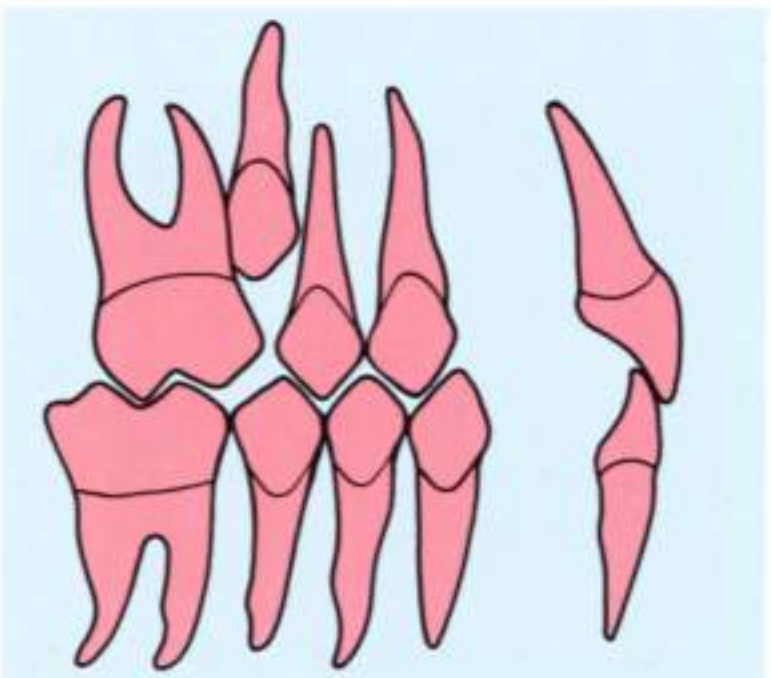


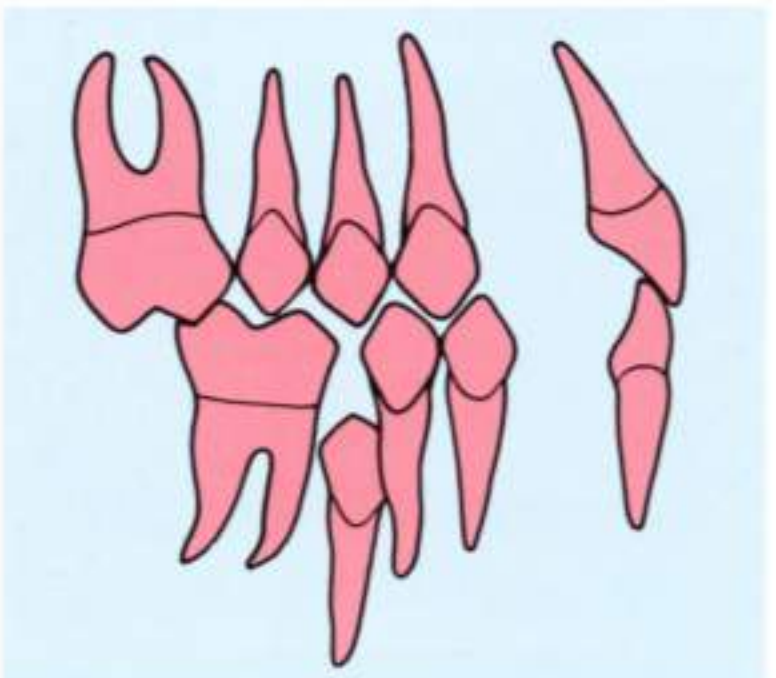


Reconstruction of occlusal relationships

566 Class I malocclusion
Left: Distoclusion of the first molars by one premolar width in the presence of a normal jaw relationship. The distoclusion has occurred on account of mesial migration of the upper first molar with loss of space for the second premolar.

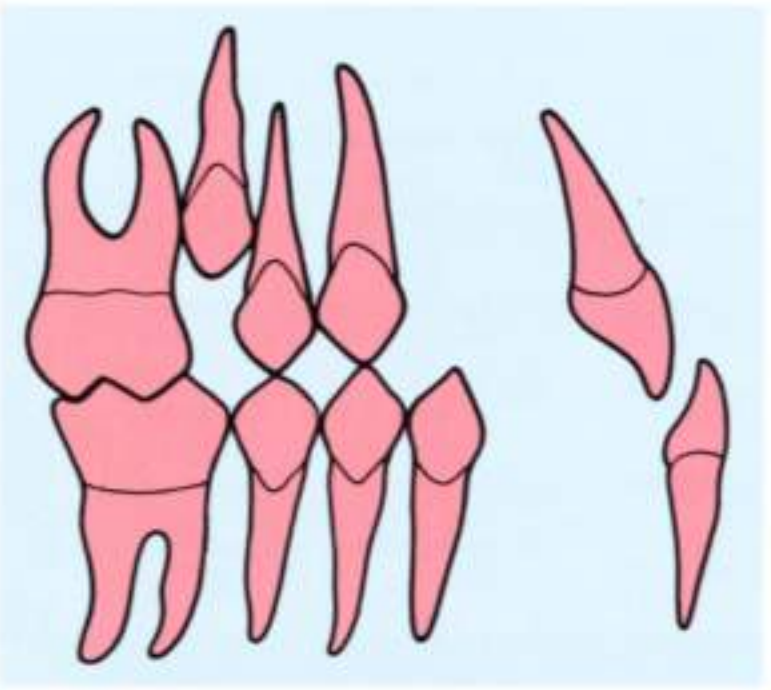
Right: Mesioclusion of the first molars by $^{3}/_{4}$ premolar width. Reconstruction of the mesial drift of the lower molar reveals a Class I jaw relationship.

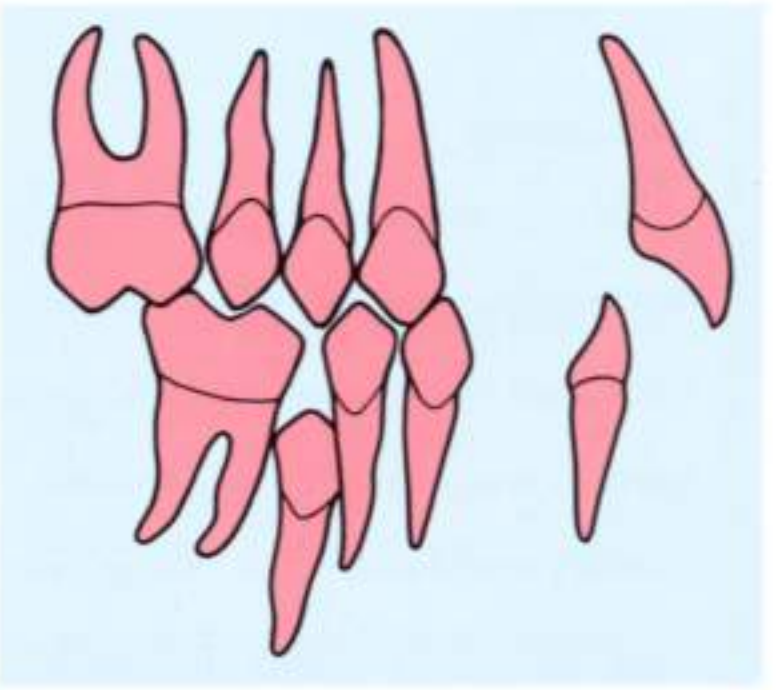




567 Class II and Class III malocclusions
Left: Neutroclusion of the first molars in a Class III malrelationship of the jaw bases by $^{1}/_{2}$ premolar width resulting from mesial drift of upper first molar.

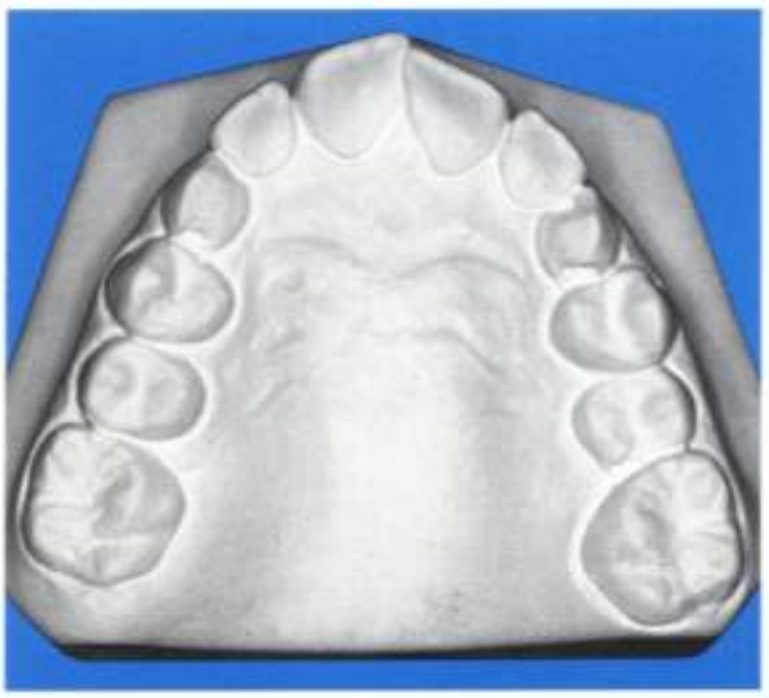
Right: Mesioclusion of first molars by one premolar width in the presence of a Class II jaw relationship. The discrepancy between the occlusal relationship and the dental base relationship results from mesial migration of the lower first molar with space loss for the second premolar (*Eschler* et al., 1971)





mandibular jaw relationships. This difference is particularly important for sagittal analysis of intermaxillary relations as there is a clear distinction between the occlusal malrelationships and the anteroposterior jaw malrelationships. Intermaxillary skeletal discrepancies can only be assessed directly from the occlusal relations if no tooth migration has occurred. This finding can be ascertained by intramaxillary symmetry measurements. If teeth have been displaced in mesial or, less often, in distal direction as a result of tooth drift, then the amount of these dental shifts have to be evaluated first ("reconstruction of the occlusion," according to Grünberg, "thinking back," according to Schwarz). Taking the dental malpositions into account the thus reconstructed occlusal relationships reveal the true anteroposterior skeletal discrepancy of jaw relations.

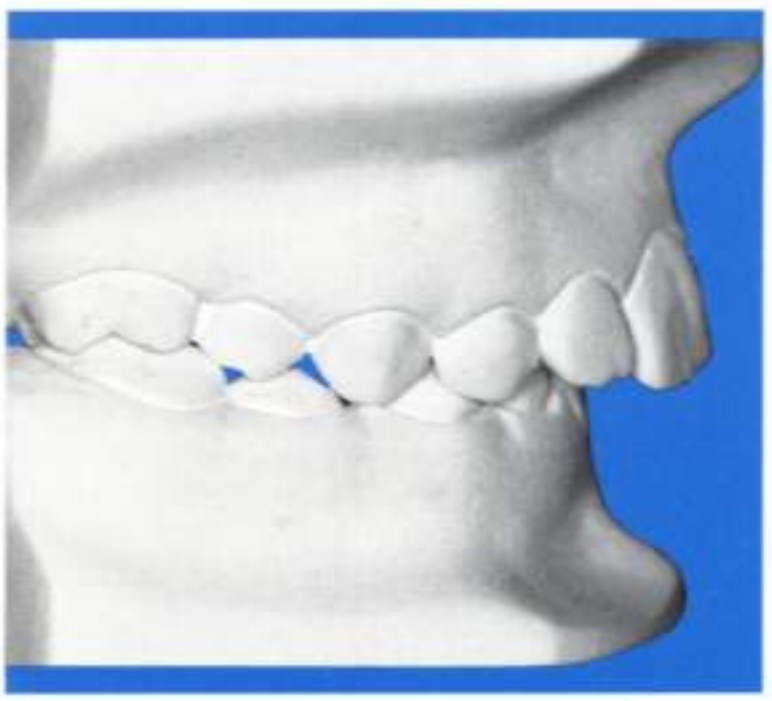
The *anterior overbite* is regarded as excessive if it measures more than 2–3 mm. A nondentally or nongingivally supported overbite in the presence of a positive overjet signifies an orofacial dysfunction.

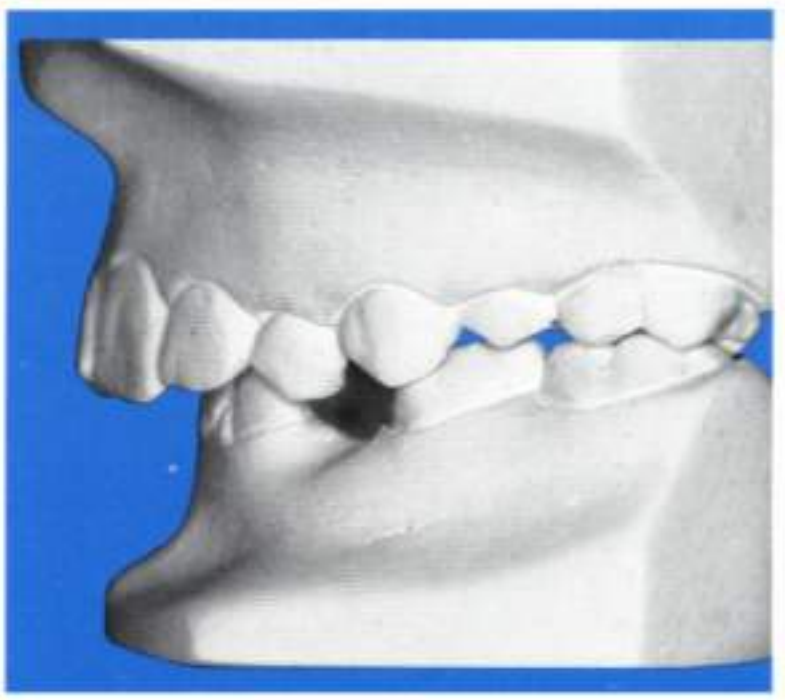


Reconstruction of occlusion – Case example –

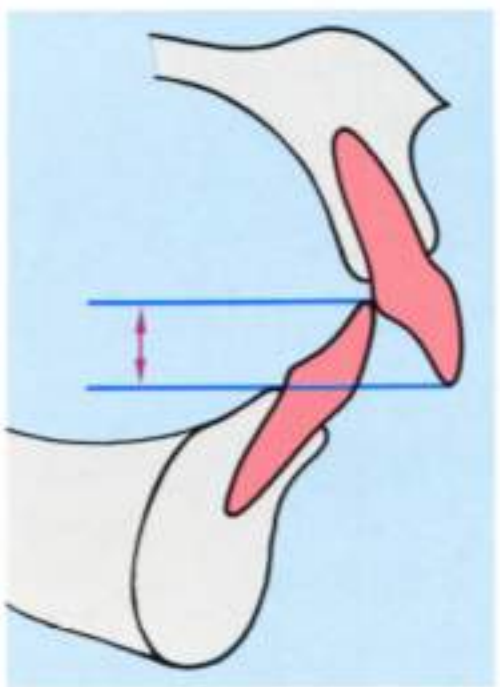
568 Mesial migration in the maxillary and mandibular arch
Left: Mesial position of the upper right posterior teeth by about 1 mm, and about 2.6 mm on the left side.

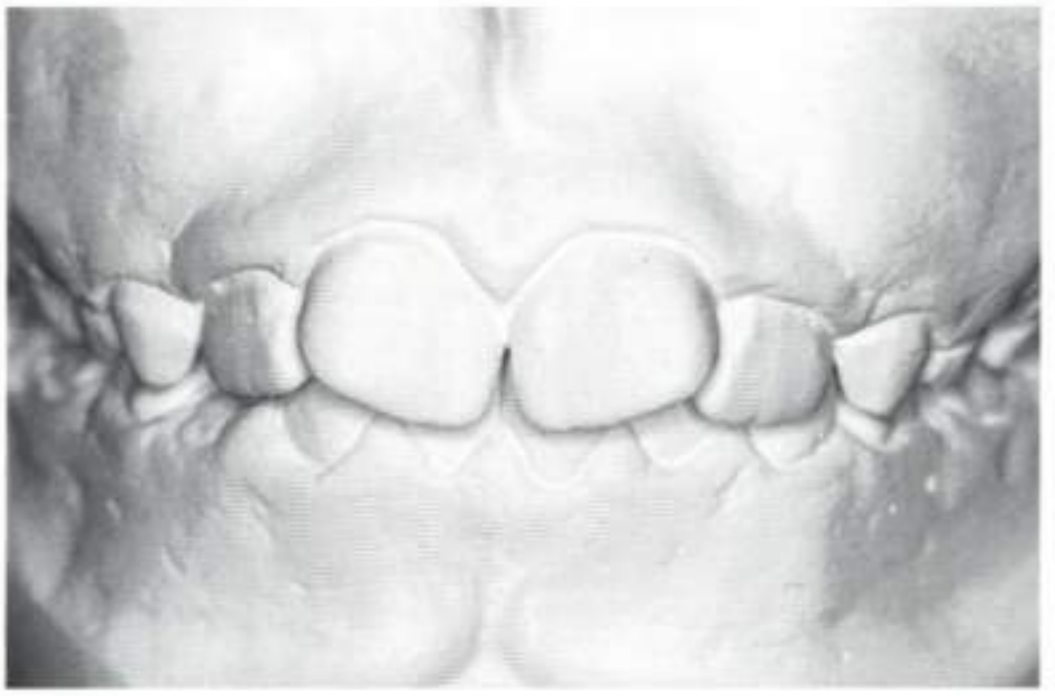
Right: Mesial drift of the lower posterior teeth as a result premature loss of deciduous teeth in the supporting zones: on the right side about 5 mm, on the left side about 6 mm.





569 Occlusal relations versus anteroposterior jaw relationships
Bilateral neutroclusion of first molars. After analyzing the degree of mesial migration, which has been more extensive in the mandibular than maxillary arch, the reconstructed occlusal relationships, reveal a skeletal Class II malocclusion.





570 Determination of overbite
The upper incisal edge is projected with a pencil mark on the labial surface of the lower central incisor parallel to the occlusal plane

Left: The distance between this mark and the lower incisal edge represents the degree of overbite.

In an open bite case, the vertical distance between the incisal edges is measured.

Study Cast Analysis – Record Sheet

Three-dimensional analysis of the dentition.

S I (Sum of incisors) Upper arch _____ Lower arch _____ mm

	Transverse	Sagittal	Vertical
Maxillary arch	Anterior area: Dental midline shift: mm right/left Diastema: mm Posterior region: 14 | : MPR 24 | : MPR 14 | : | 24 16 | : MPR 26 | : MPR 16 | : | 26 (Actual | Standard | Diff.) Compensating curve: right left	Anterior area: (Actual | Standard | Diff.) L_u Posterior area: Supporting zones: (Actual | Standard | Diff.) right left Space required: _____ mm Space available: _____ mm Difference: _____ mm Compensating curve: right left	*Supraposition/Overeruption* Individual tooth: Groups of teeth: *Infraposition/Submergence* Individual tooth: Groups of teeth: *Palate height 6/6:*
Mandibular arch	Anterior area: Dental midline shift: mm right/left Diastema: mm Posterior area: 44 | : MPR 34 | : MPR 44 | : | 34 46 | : MPR 36 | : MPR 46 | : | 36 (Actual | Standard | Diff.) Compensating curve: right left	Anterior area: (Actual | Standard | Diff.) L_u Posterior area: Supporting zones: (Actual | Standard | Diff.) right left Space required: _____ mm Space available: _____ mm Difference: _____ mm Compensating curve: right left	*Supraposition/Overeruption* Individual tooth: Groups of teeth: *Infraversion/Submergence* Individual tooth: Groups of teeth:
Occlusion	Cross-bite Nonocclusion buccal lingual Midline shift: mm right/left	Overjet _____ mm Occlusion 16 | / 46 | 13/53 | / 43/83 | | 26 / 36 | | 23/63 / 33/73 | Jaw relationship: _____	Overbite _____ mm Open bite _____ mm anterior/lateral right/left Deep bite: supported / unsupported dentally gingivally

* For Rees and Bolton measurements, special evaluation sheets are used.

Treatment Plan

The individual findings are compiled to form the comprehensive diagnostic assessment. This *comprehensive diagnosis* describes those features of the malocclusion which must be considered when planning treatment. These include abnormalities of the maxilla, mandible, and the occlusion, as well as the functional and craniofacial relationships.

Finally, a detailed treatment plan is prepared, subdivided into chronological treatment stages. For each stage the necessary treatment measures and appliances are recorded. Such a plan serves as a guide for therapy which may extend over a 3- to 4-year period. At the end of the individual treatment stages, the plan – depending on the intermediate results – may have to be confirmed or changed. At the end of treatment, a critical appraisal is made in order to compare the result of treatment with the original goals. From p. 238 onward three examples can be found which illustrate such planning.

Comprehensive diagnostic assessment:

Maxilla:

Mandible:

Occlusion:

Treatment plan in stages:

Treatment stages:	Extractions:	Treatment measures:

Changes:

Prognostic assessment:

Final critical assessment:

571 Chart of orthodontic treatment plan

After the diagnosis of the overall problem, the individual treatment stages are listed chronologically, together with any planned tooth extractions and orthodontic or dentofacial orthopedic appliances.

Under the heading *"changes"*, possible alterations from the above-mentioned treatment plan should be recorded since they may be necessary, depending on reaction to treatment, especially with respect to the intermediate results.

Under the heading *"prognostic assessment,"* favorable and unfavorable factors concerning the planned treatment are described.

The section *"final critical assessment"* includes a comparison of the intended treatment for the case in question and other therapeutic possibilities.

Treatment Planning Case Example 1

7½-year-old girl with anterior open bite, in conjunction with maxillary prognathism and bimaxillary dental protrusion.

History	Infant feeding:	Breast: 2 months, bottle till 6 months
	Postnatal development:	First teeth: 6 months, first steps: 11 months, talking: started 13 months
	Orofacial dysfunctions:	Pacifier up to the age of 4 years, thumb-sucking up to 6 years, also during day-time
	Illnesses:	Coughs and colds
Etiology of malocclusion	Orofacial dysfunctions (tongue-thrusting, lip-sucking)	
General examination	Extraoral examination:	Shape of skull: Broad
		Shape of face: Broad
		Lips: Everted
		Nasal profile: Reduced nasolabial angle

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Dental status

Absence of third molars

X-ray		17		15	14	13					23	24	25		27		X-ray
			16	55	54	53	12	11	21	22	63	64	65	26			
R																	L
			46	85	84	83	42	41	31	32	73	74	75	36			
X-ray		47		45	44	43					33	34	35		37		X-ray

c Tooth carious z Tooth not to be maintained x Tooth extracted m Tooth malformation
a Nonvital tooth f Large restoration s Wear facets

Examination of the oral cavity

Frenum attachments:	deep insertion in the upper arch
Gingiva:	normal, no inflammation
Periodontal disease:	none
Oral mucosa:	normal
Palate:	average height
Apical base:	maxillary arch – large sagittally, normal transversally, mandibular arch – normal

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Frontal and profile facial photographs

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Occlusal relationships

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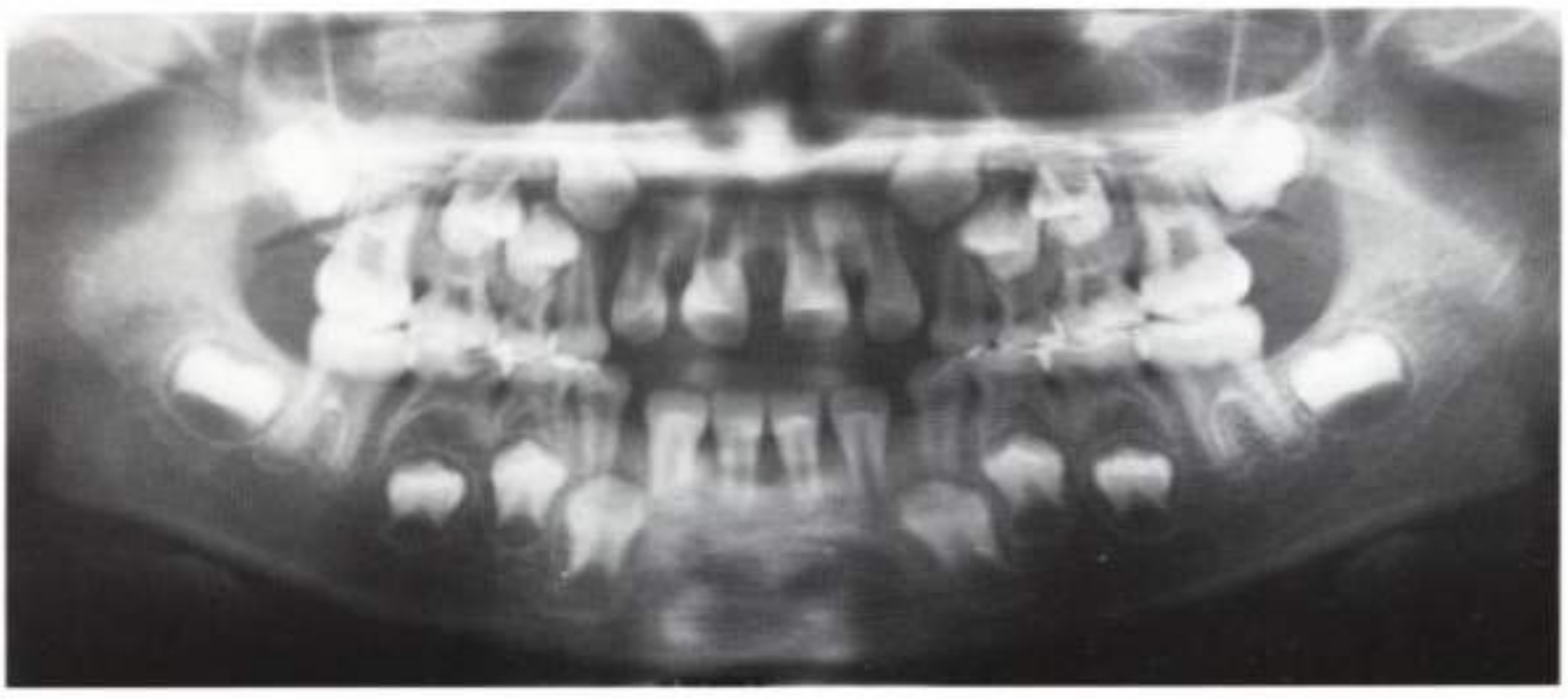
The dental arches



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Panoramic radiograph

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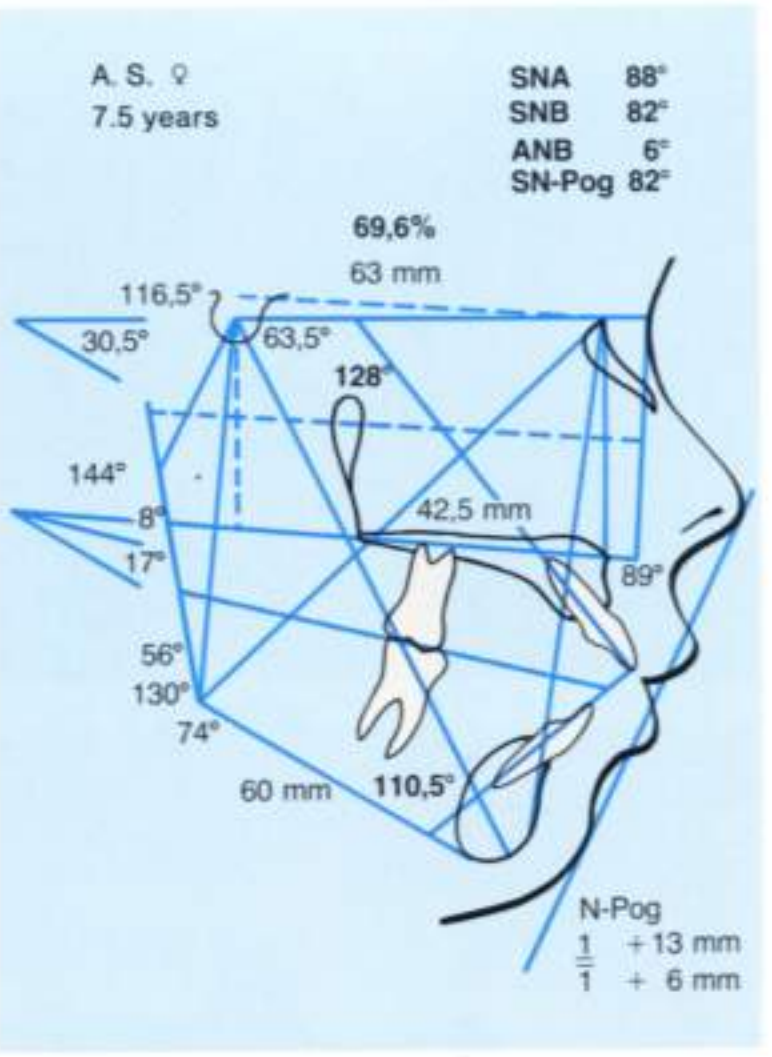
Original cephalogram

Cephalometric tracing



Results of the cephalometric analysis

Prognathic facial type with horizontal growth tendency.
Skeletal Class II relationship with skeletal imbalance the of maxilla. Bimaxillary dental protrusion of incisors and dentoalveolar open bite.

Craniofacial skeleton:
Sagittal: prognatic,
small sella angle,
low position of glenoid fossa.
Vertical: horizontal growth pattern and decreased sum of posterior angles.

Maxilla:
Prognathic with anteinclination,
short base.

Mandible:
Prognathic, short base,
wide symphysis,
sagittal discrepancy 6 mm.

Incisors:
Labial tipping and anteposition to N-Pog-line of upper and lower incisors.

Lip profile:
Lips everted and protrusive to the esthetic line.

Profile analysis

Backward-slanting anteface.
Enlarged lip step

Analysis of study casts

Upper arch:

- Asymmetric narrow arch
- Spacing of the anterior teeeth
- Midline diastema
- Upper right central incisor tipped distally
- Supporting zones intact
- Infraversion of incisors

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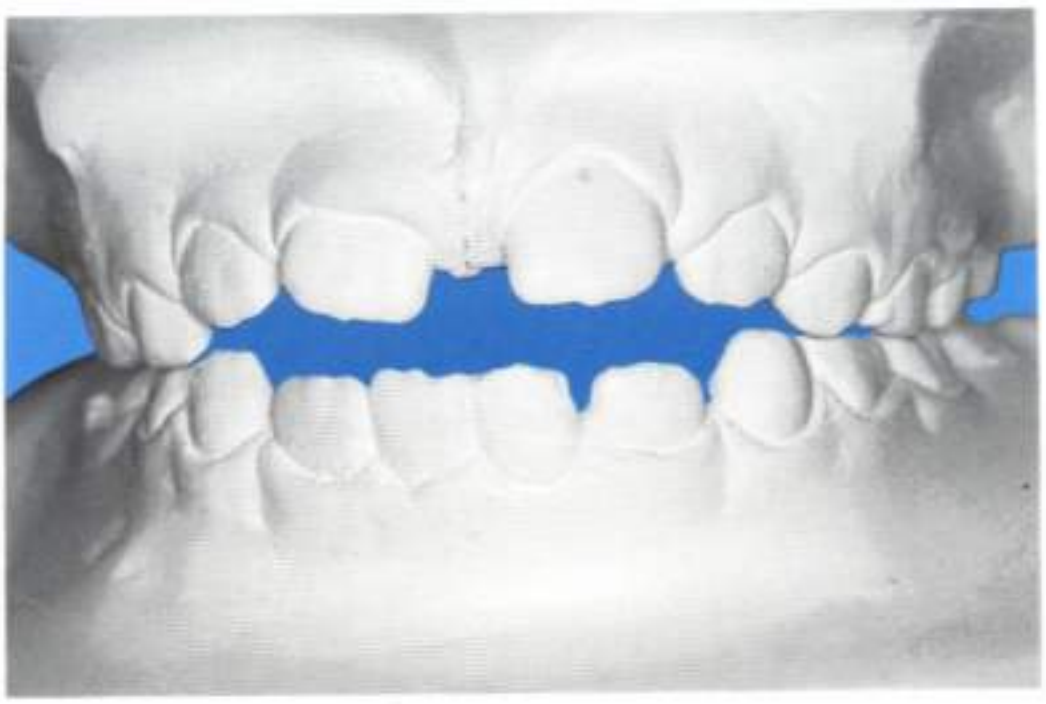

Lower arch:

- Asymmetric narrow arch
- Midline shift of 2 mm to the right
- Supporting zones intact
- Infraversion of incisors
- Supraversion (over-eruption) of posterior teeth

Occlusion:

Anterior open bite: 4 mm
Overjet: 4 mm

Anteroposterior jaw relationship: distal.
Occlusal interference at the upper right deciduous canine.

Occlusal relationships:

– first molar region left: 1 premolar width distal	– Canine region left: ¼ premolar width distal
right: ½ premolar width distal	right: Class I relationship

bilateral Class II relationship, more pronounced on the left than on the right side; abrasion of deciduous canines

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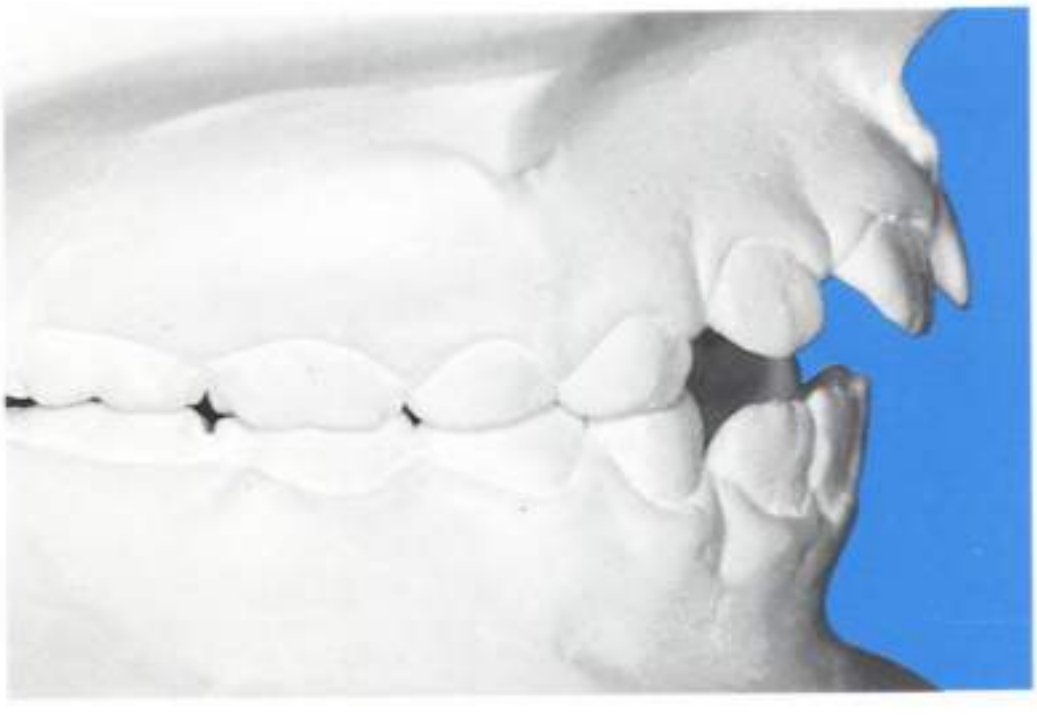

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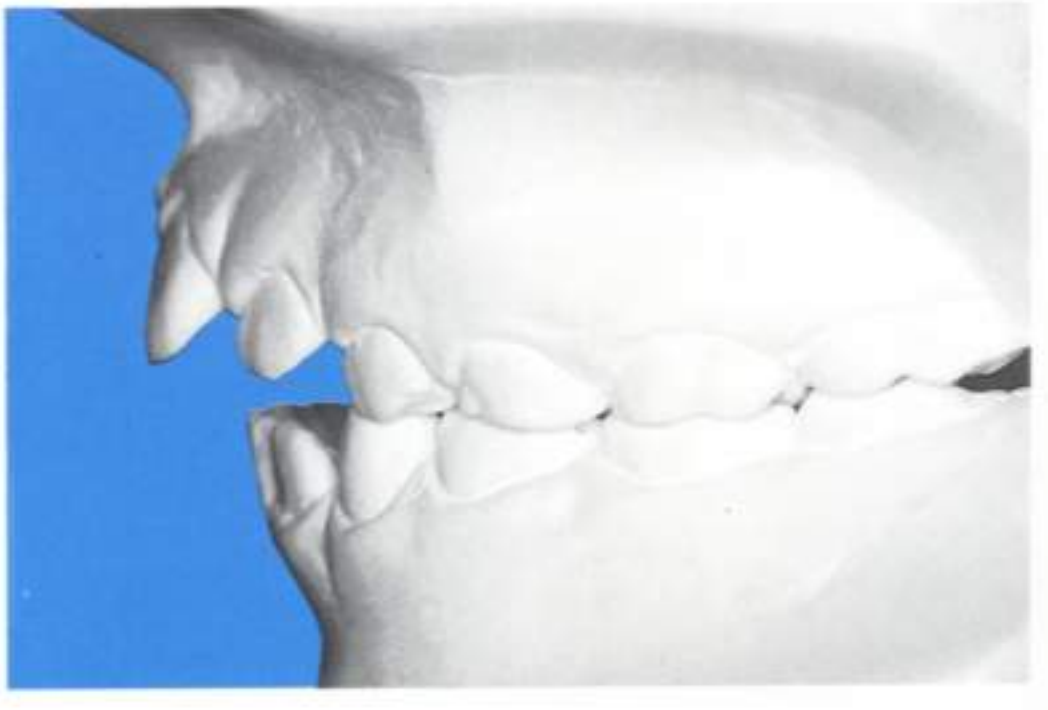

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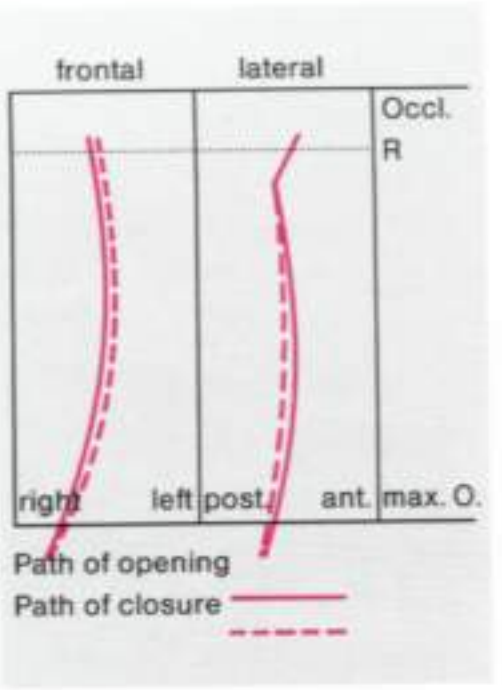

Functional analysis

Occlusal position:	forward
Postural rest position:	posterior
Mandibular sliding movement:	2 mm anteriorly
Temporomandibular joint:	amount of maximal incisal opening: 5 cm, path of opening C-shaped to the right

Orofacial dysfunctions

Swallowing pattern:	visceral, with contraction of the perioral muscles
Tongue dysfunctions:	tongue-thrusting with forward posture of tongue
Lip dysfunctions:	lip-sucking with tongue-lip contact
Speech defects:	interdental lisping, peripheral disturbance of sound formation
Breathing:	nasal-breathing

Comprehensive diagnosis

Morphology:	Prognathic facial type with anterior open bite, anteinclination of the maxilla, and horizontal growth tendency.
Function:	Tongue and lip dysfunctions, visceral swallowing pattern.

Treatment plan in stages

	Requirements		*Appliances*
1. Stage	Elimination of orofacial dysfunctions	→	Oral screen with tongue crib
2. Stage	Correction of maxillary incisor position	→	Bracketing and banding of maxillary incisors and upper first molars
3. Stage	Correction of antero-posterior jae discrepancy, retraction of anterior teeth. Guidance of tooth eruption including retention	→	Activator, combined with headgear

Course of Treatment

First stage, 12 months; second stage, 6 months; third stage (retention) until full eruption of permanent dentition.	*Duration*
Myofunctional therapy may be indicated if compensatory tongue-thrust persists following correction of open bite.	*Changes*

Treatment was carried out according to the original treatment plan.

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Details on treatment mechanics will be discussed in the second volume "Orthodontic Treatment".

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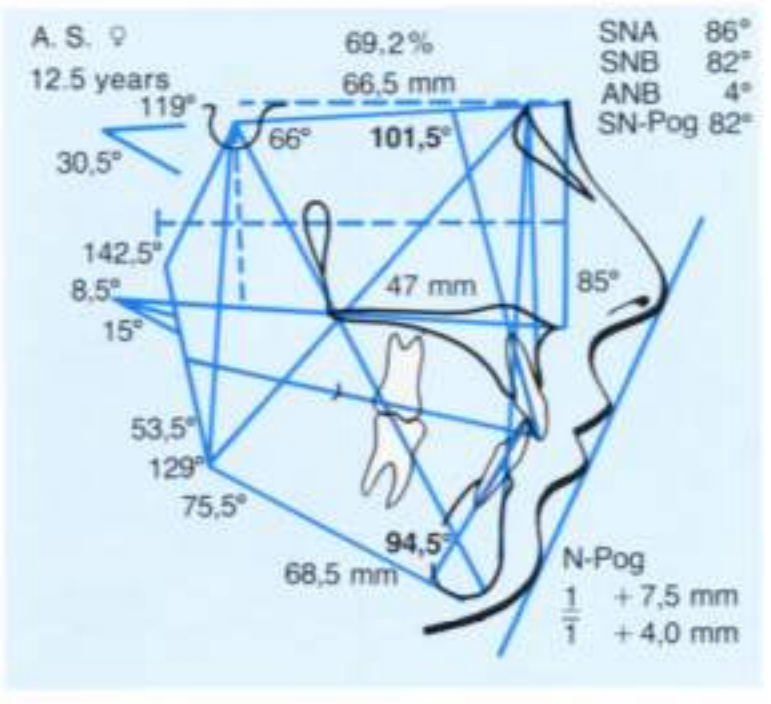
Panoramic radiograph at the end of treatment



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Treatment finished at 12 years of age after the retention period.

Treatment Planning Case Example 2

12-year-old girl with mesioclusion.
Bilateral cross-bite, slight anterior open bite, and crowding in upper arch.

History	Infant feeding:	Breast: 1.5 months, bottle: 12 months, spoon: started 6 months
	Postnatal development:	First tooth: 8 months, first steps: 11 months, talking: started 12 months
	Orofacial dysfunctions:	Pacifier till 2nd year, nail-biting still continues; sleeps with open mouth
	Illnesses:	Coughs and colds, hyperplasia of adenoids and tonsils
Etiology of malocclusion	Heredity (craniofacial morphology, hyperplasia of tonsils)	
	Orofacial dysfunctions (tongue-thrusting, oronasal breathing)	
General examination	Extraoral examination:	Shape of skull: Narrow Shape of face: Narrow, oval Lips: Dry and narrow upper lip, competent lip morphology, negative lip step Chin: Well developed

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Dental status

Hypoplasia of occlusal surfaces of upper first permanent molars

	X-ray															28	X-ray
R			17	16	15	14	13	12	11	21	22	23	24	25	26	27			L
			47	46 f	45	44	43	42	41	31	32	33	34	35	36 f	37		
	X-ray	48															38	X-ray

c Tooth carious
a Nonvital tooth
z Tooth not to be maintained
f Large restoration
x Tooth extracted
s Wear facets
m Tooth malformation

Examination of the oral cavity

Frenum attachments:	weak in both arches
Gingiva:	hyperplastic in upper anterior region
Periodontal disease:	none
Oral mucosa:	normal
Palate:	high
Apical base:	maxillary arch – large mandibular arch – small

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Frontal and profile facial photographs

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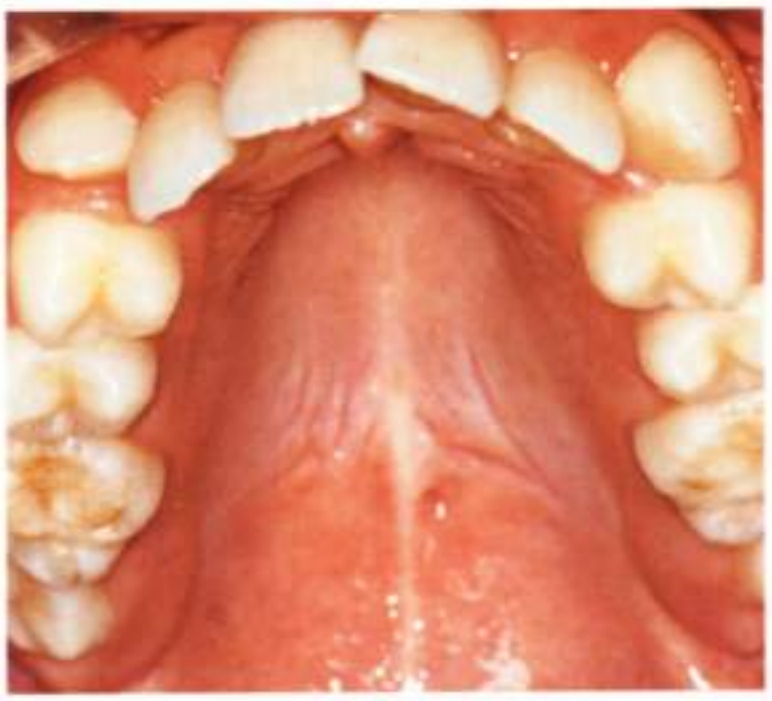
Occlusal relationships



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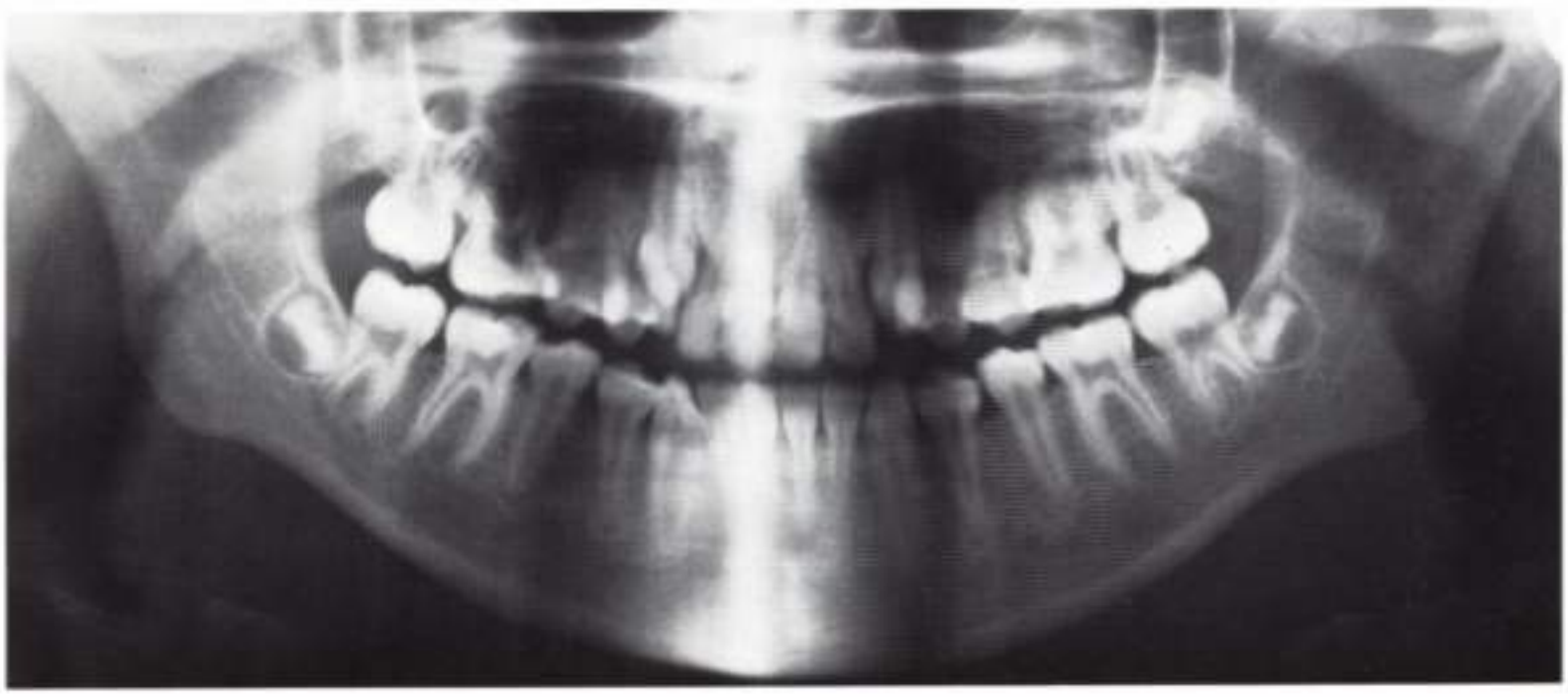
The dental arches



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Panoramic radiograph

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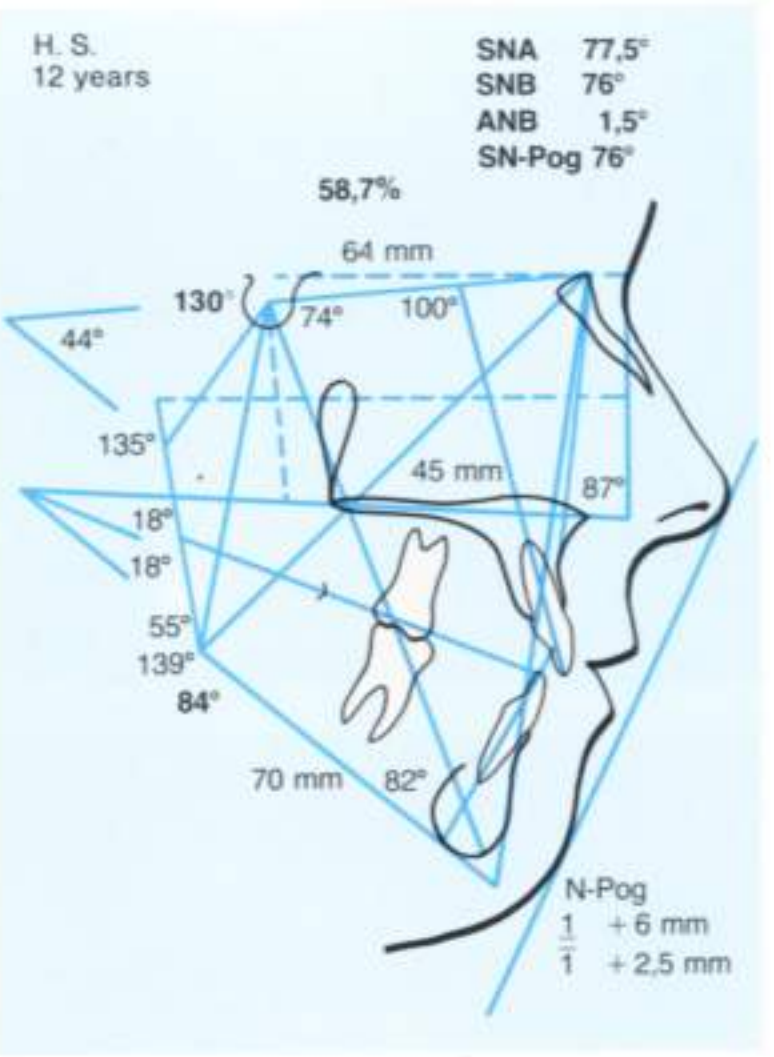
Original cephalogram

Cephalometric tracing



Results of the cephalometric analysis

Retrognathic facial type with extreme vertical growth pattern.
Class III tendency, partly compensated by posterior position of the glenoid fossa and backward rotation of the mandible.

Craniofacial skeleton

Sagittal: retrognathic,
large sella angle,
posterior position of glenoid fossa.

Vertical: vertical growth tendency with
increased sum of posterior angles
and lower gonial angle.

Maxilla: Retrognathic, anteinclination, normal base length.

Mandible: Normal arch form with lower incisors tipped lingually, sagittal discrepancy 1 mm, total discrepancy 3 mm.

Incisors: Linguoversion of lower incisors, maxillary incisors labial to N-Pog-line with normal axial inclination.

Lip profile: Upper and lower lips retrusive, behind the esthetic line; large nasolabial angle.

Profile analysis

Average (= biometric) face.
Predominance of lower face height

Analysis of study casts

Upper arch:
- Anterior crowding
- Asymmetric narrow arch
- Buccoversion of upper canines
- Arch length deficiency
- Midline shift of 2 mm to the right
- Infraversion of anterior teeth
- High palate

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Lower arch:
- Rotation and buccoversion of lower canines
- Rotation and expanded width of premolars
- Adequate arch length
- Overeruption of incisors
- Infraversion of posterior teeth

Occlusion:

Bilateral cross-bite
Cross-bite of upper lateral incisors and lower canines
Overjet: 4 mm
Anteroposterior jaw relationship: mesial
Open bite: 1 mm
Occlusal interference at lower second molars
Working side on the right

Occlusal relationships:

– 1st molar region	– canine region
left: ½ premolar width distal	left: ½ premolar width distal
right: ½ premolar width distal	right: ¼ premolar width distal

Mesial migration of upper posterior teeth.
Reconstruction of dental shifts reveal a Class III relationship

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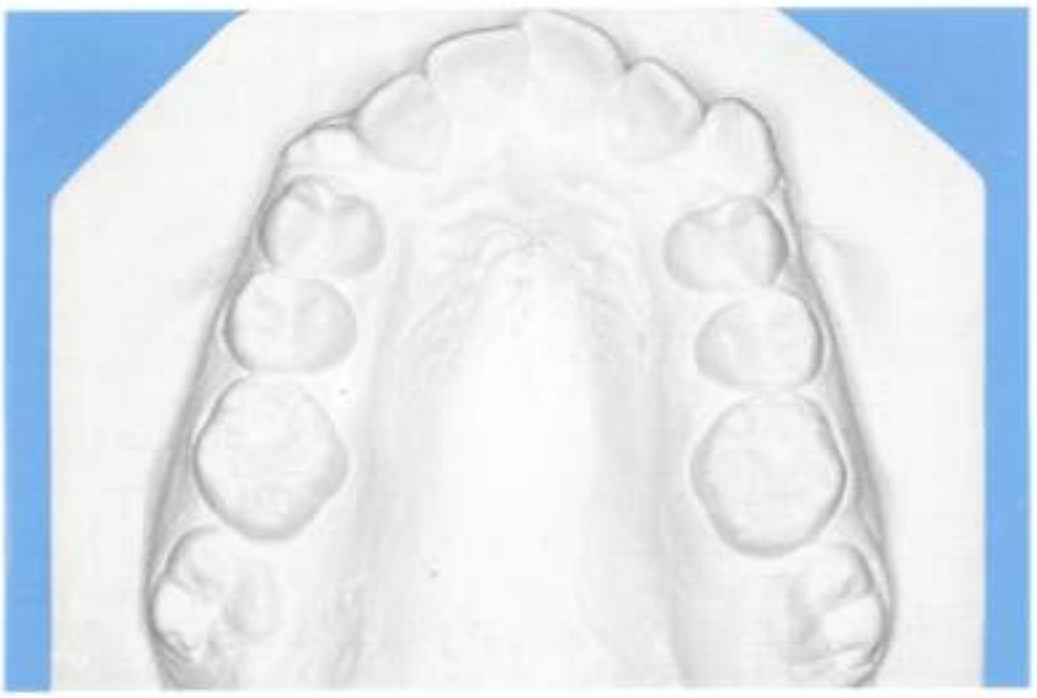

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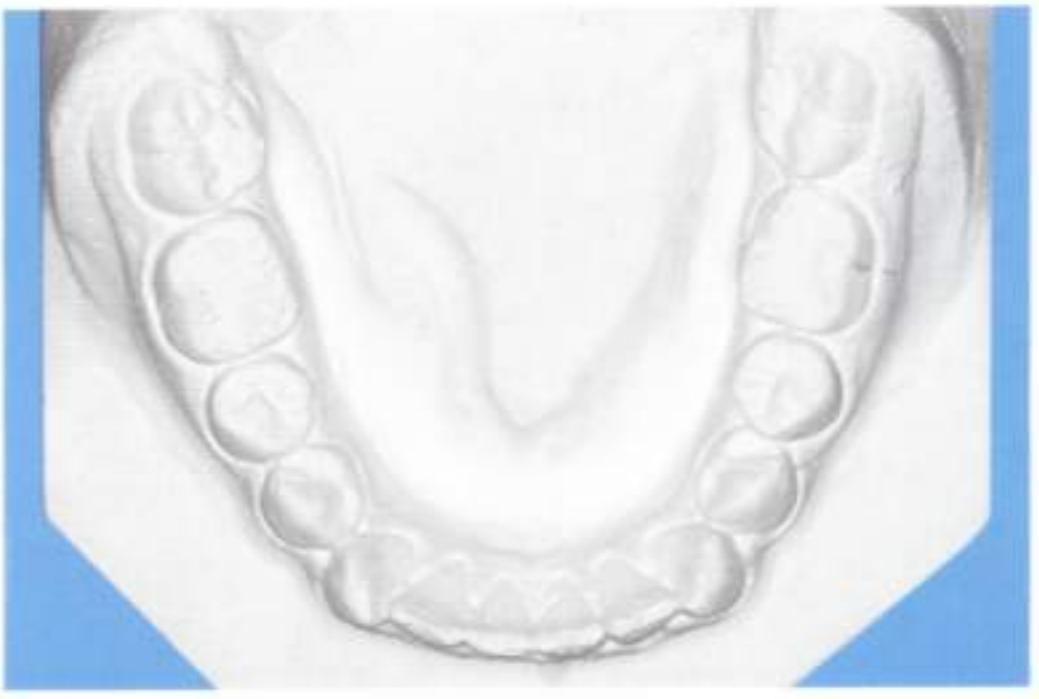

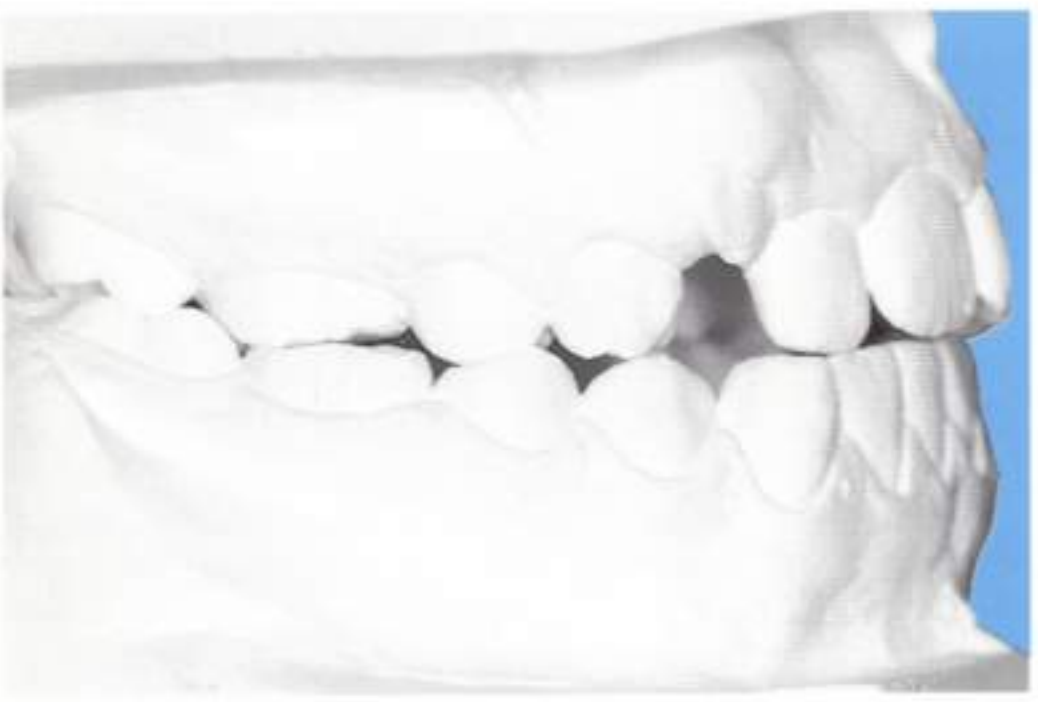

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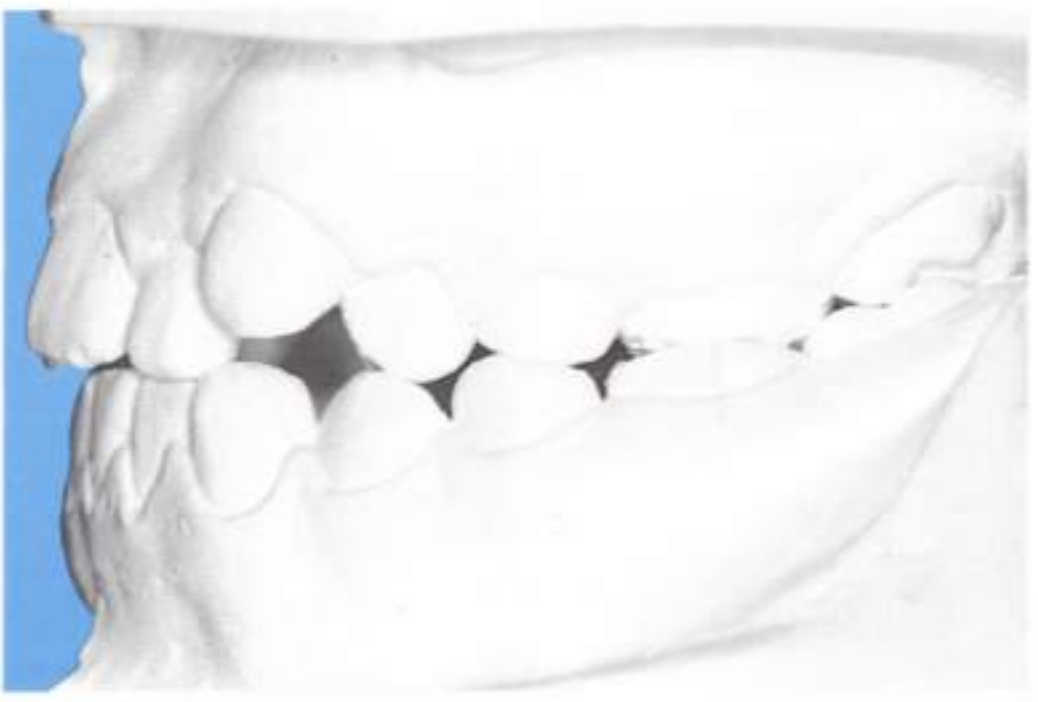

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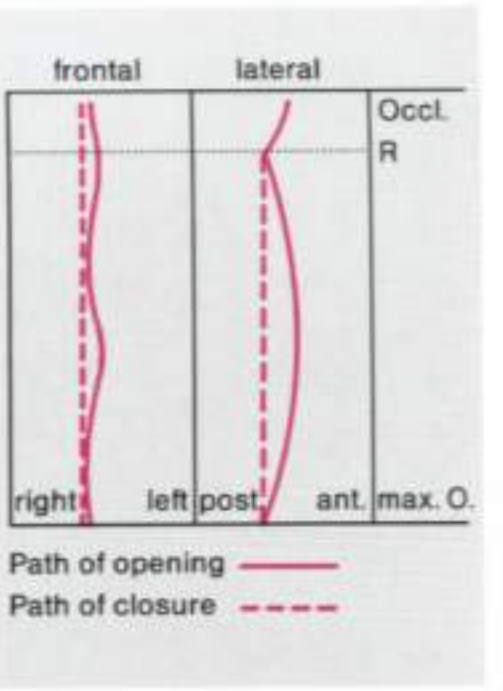

Functional analysis

Occlusion position:	forward
Postural rest position:	posterior
Temporomandibular joint:	amount of maximal interincisal opening: 5.3 cm muscle palpation: pain on pressure left and right lateral ptyerygoid muscles
Occlusal interferences:	at lower second molars

Orofacial dysfunctions

Swallowing pattern:	complex tongue-thrust swallow
Tongue dysfunction:	thrusting, large tongue, postured anteriorly
Speech defects:	interdental lisping
Breathing:	mouth-breathing

Comprehensive diagnosis

Morphology:	Bilateral cross-bite, mesioclusion, retrognathic facial type, vertical growth tendency.
Function:	Orofacial dysfunctions, mouth breathing, abnormal tongue function, nail-biting.

Treatment plan in stages

	Requirements		*Appliances*
1. Stage	Correction of bilateral cross-bite	→	Rapid maxillary expansion appliance
2. Stage:	Extraction of all four first premolars and alignment of dental arches	→	Full fixed appliances in upper and lower arch, high-pull headgear
3. Stage:	Retention	→	Removable retainers

Course of treatment

Active treatment 2 years; long-term retention until 16 years of age.	*Duration*
Following rapid maxillary expansion, a reevaluation of the case is indicated; should this reveal presence of the upper right third molar, the extraction of first molars can be considered.	*Changes*

Treatment was carried out according to the original treatment plan.

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Details on treatment mechanics will be discussed in the second volume "Orthodontic Treatment".

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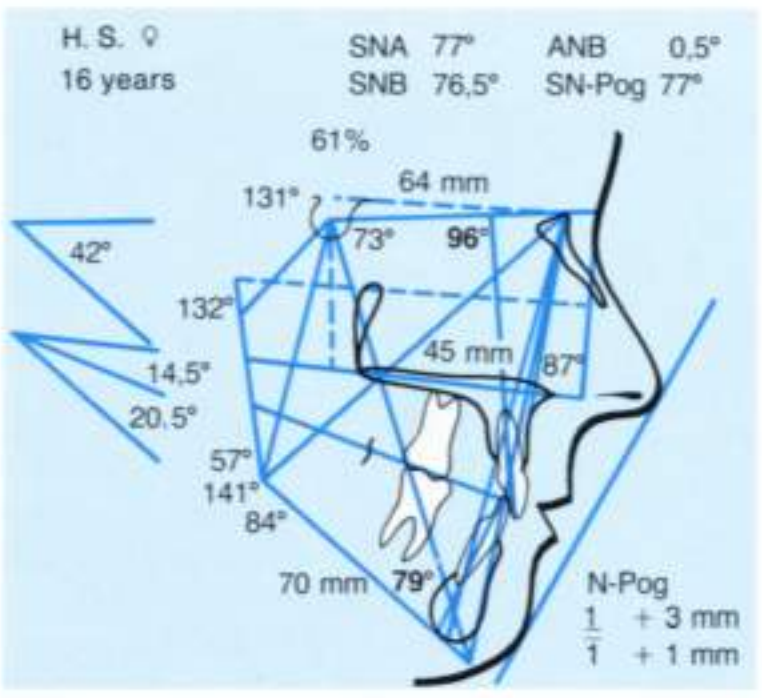

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End of treatment at age 16 after the retention period.

Treatment Planning Case Example 3

25-year-old female patient with anterior open bite, distoclusion, and crowding in the upper and lower arch

Treating an adult patient, certain age-related problems must be taken into account.

These are:
- Periodontal condition, which must be especially examined and if necessary improved prior to adult orthodontic treatment.
- Decreased bone elasticity, remodeling potential and reduced turnover rate.
- Treatment without damaging the related tissues.
- Absence of growth; therapy cannot effect skeletal changes. Treatment is restricted to the dentoalveolar base.

History

7-year history of thumb-sucking; orthodontic treatment with active removable appliances from the age of 9 to 12 years.
Treatment included extraction of lower right central incisor. After eruption of all permanent teeth, the molars were "adjusted" by grinding (the patient was treated at a different place).

Etiology of malocclusion

Heredity: vertical configuration of the craniofacial skeleton, primary crowding
Orofacial dysfunctions: long-standing digit-sucking habit, compensatory tongue dysfunction

General examination

Extraoral Examination:
Shape of skull: narrow
Shape of face: narrow, oval, long
Lips: narrow upper lip, lower lip everted and tense, deep mentolabial sulcus
Chin: flat, receding

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Dental status

Deep restorations in the molars

	X-ray																X-ray
R		18 f	17 f	16 f	15	14	13	12	11	21	22	23	24	25	26 f	27 f	28 f		L
		48	47 f	46 f	45	44	43	42	41 x	31	32	33	34	35	36 f	37 f	38 f		
	X-ray																	X-ray

c Tooth carious
a Nonvital tooth
z Tooth not to be maintained
f Large restoration
x Tooth extracted
s Wear facets
m Tooth malformation

Examination of the oral cavity

Frenum attachments: narrow in both arches

Gingiva: hyperplastic in upper and lower anterior region

Periodontal disease:
Hygiene-index 50%
Papilla-bleeding-index 2.8 in upper arch,
3.1 in lower arch.
Pocket formation in the lower arch and upper molar region
Sub- and supragingival calculus
Tooth mobility 0 in upper arch, 2 in lower arch
Pocket depth 4 mm in upper arch approximately,
4 mm in lower arch approximately.

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Frontal and profile facial photographs

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Occlusal relationships

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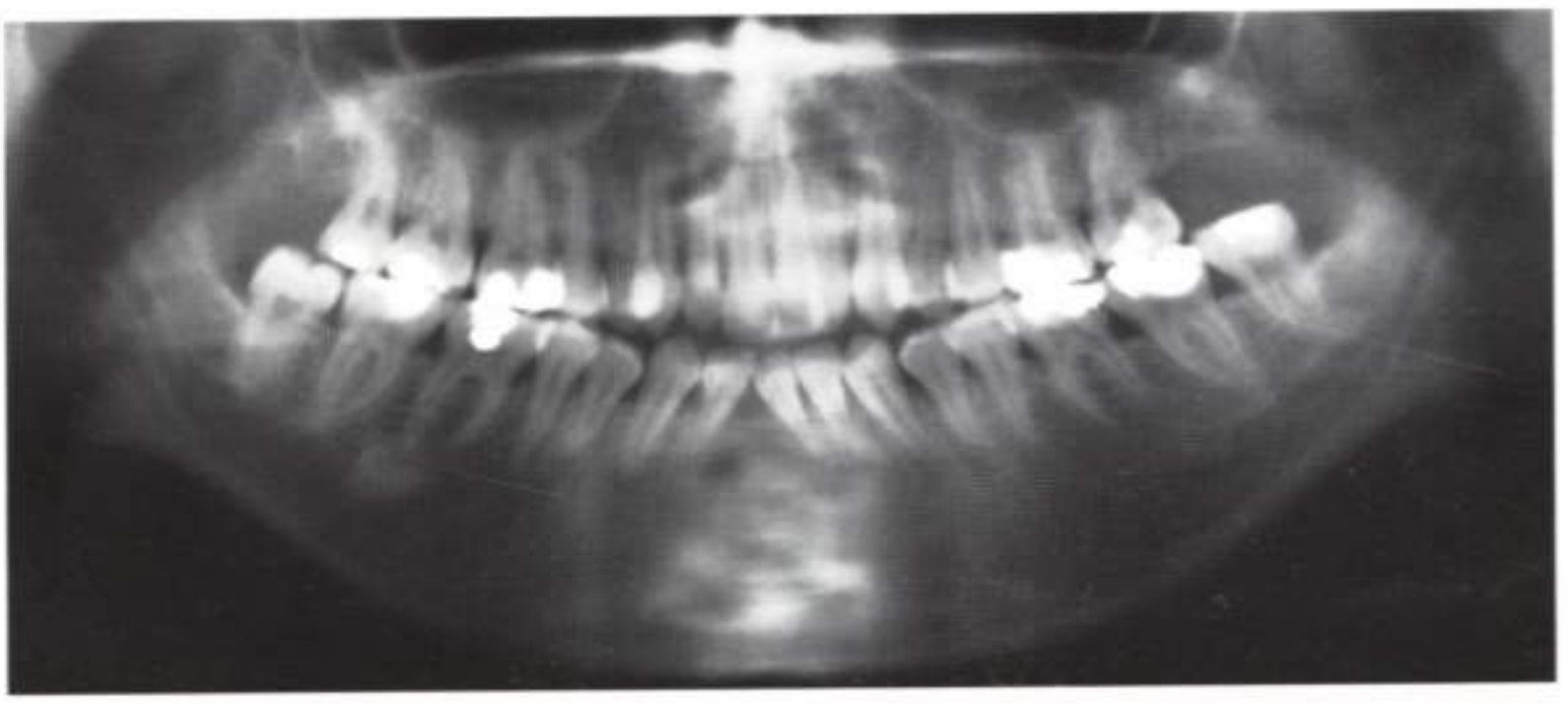
The dental arches



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Panoramic radiograph

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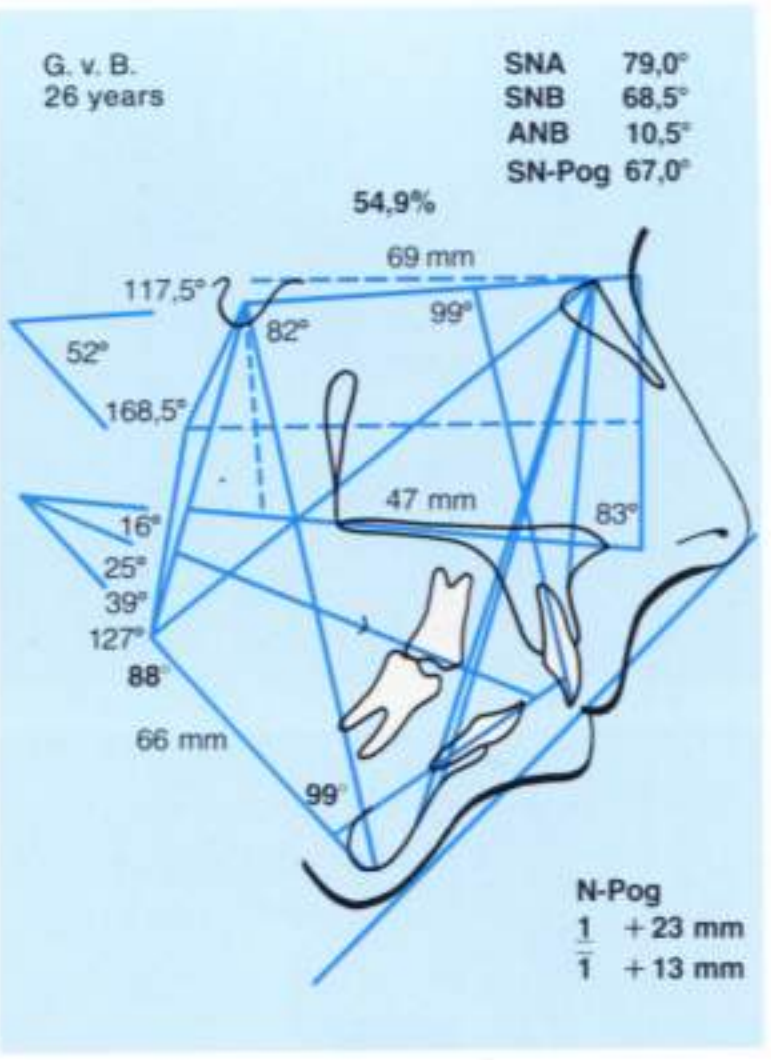
Original cephalogram

Cephalometric tracing



Results of the cephalometric analysis

Retrognathic facial type with extreme vertical configuration and extreme mandibular retrognathism.

Craniofacial skeleton:
Sagittal: retrognathic,
acute sella angle,
very large articular angle.
Vertical: vertical growth pattern with normal gonial angle, but very large lower gonial angle.

Maxilla:
Slight retrognathism, slight retroinclination, normal base length.

Mandible:
Retrognathic, short base, normal symphysis, short ramus, increased antegonial notching.

Incisors:
Anteposition in both arches,
linguoversion of upper incisors and labial tipping of lower incisors.
Mandibular sagittal discrepancy of 11 mm.

Lip profile:
Upper and lower lips everted and protrusive to the esthetic line.

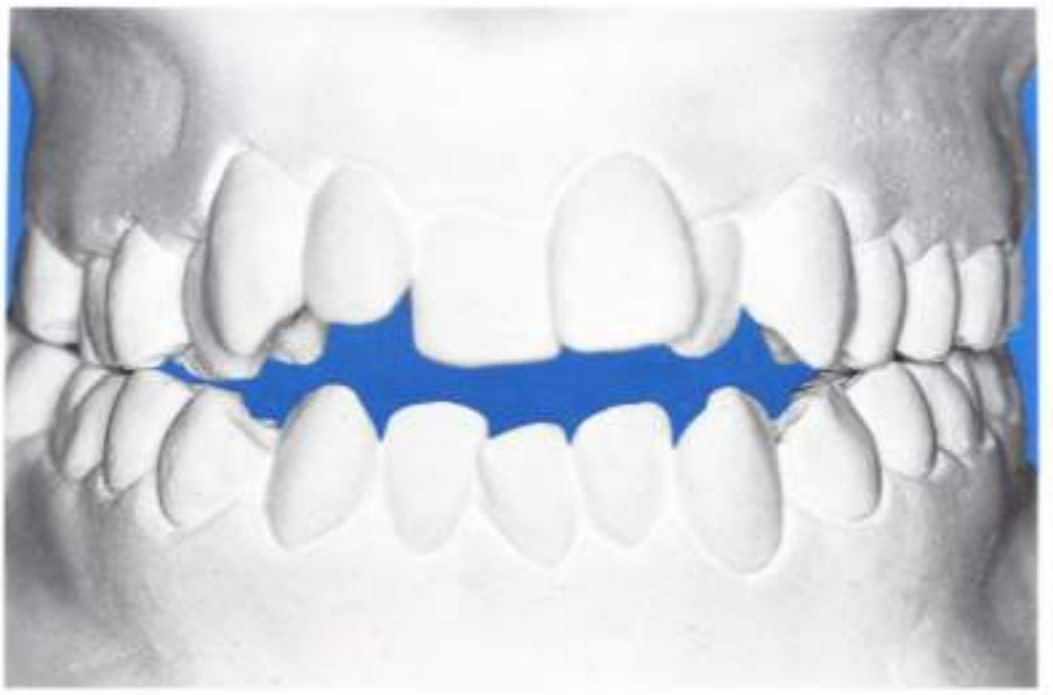
Profile analysis

Backward-slanting anteface.
Excessive lower face height

Analysis of study casts

Upper arch:

- Asymmetric narrow arch
- Midline line shift of 2 mm to the left
- Anterior crowding
- Buccoversion of tooth 13
- Linguoversion of tooth 14



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Lower arch:

- Arch anteriorly flattened, and widened posteriorly
- Anterior crowding
- Mesial migration of posterior teeth
- Mesial tipping of tooth 31 and tooth 32
- Tooth 41 extracted

Occlusion:

Bilateral distoclusion with anterior open bite from upper right first premolar to upper left second premolar.
Overjet: 8 mm.
Occlusal interference at lower right second premolar and lower left third molar.

Occlusal relationships:

- first molar region: left: 1 premolar width distal

  right: ¼ premolar width distal

- Canine region: left ½ premolar width distal

  right: Class I relationship

Mesial migration of upper and lower posterior teeth

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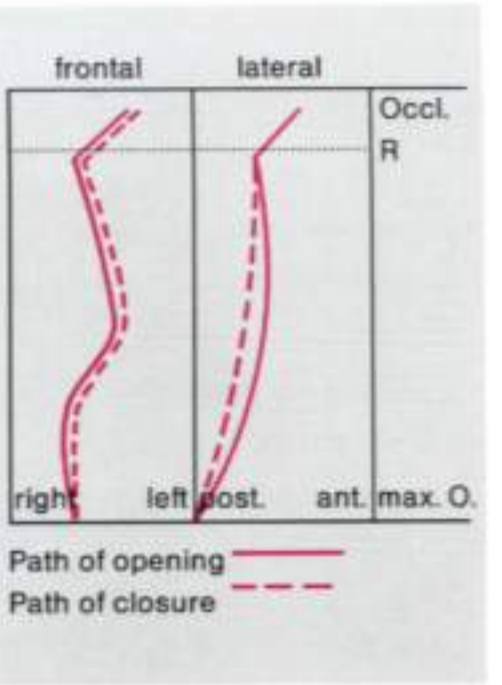

Functional analysis	Mandibular path from postural rest position to habitual occlusion with anterior sliding component	
	Temporo-mandibular joint:	amount of maximal interincisal opening: 4.5 mm; muscle palpation: pain on pressure of both lateral pterygoid muscles, S-shaped opening movement, intermediate clicking of left joint.
Orofacial dysfunctions	Swallowing pattern:	visceral, with contraction of perioral musculature
	Tongue dysfunctions:	tongue-thrusting and forward posture
	Lip dysfunctions:	incompetent lips, lower lip-sucking, tongue-lip contact
Comprehensive diagnosis:	Morphology:	Skeletal anterior open bite, crowding, mandibular retrusion, increased overjet.
	Function:	Orofacial dysfunctions, abnormal tongue and lip function, symptoms of temporomandibular joint dysfunction.

Treatment plan in stages

	Requirements		*Appliances*
1. Stage	Extraction of upper first premolars	→	Full fixed appliances in the upper and lower arch.
	Levelling and alignment of the arches		Insertion of flexible arch wires
2. Stage	Correction of open bite	→	Insertion of heavy arch wires, use of intermaxillary elastics
3. Stage	Retention	→	Positioner, removable retainers, possibly permanent retention in mandibular dental arch
4. Stage	Improving facial profile	→	Genioplasty

Course of Treatment

First treatment stage

Duration 11 months

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Alignment and space closure in the upper arch using highly flexible, so-called exotic arch wires.

Second treatment stage

Duration 7 months

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The open bite is corrected, using heavy archwires and short intermaxillary elastics. *Note:* Labial stripping of lower anterior teeth.

Third treatment stage

Retention stage

616

Retention stage. Retention with a positioner, and following genioplasty continued with removable retainers. Periodontal care, with possible gingival grafts.

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Intraoral photographs at the end of the third treatment stage

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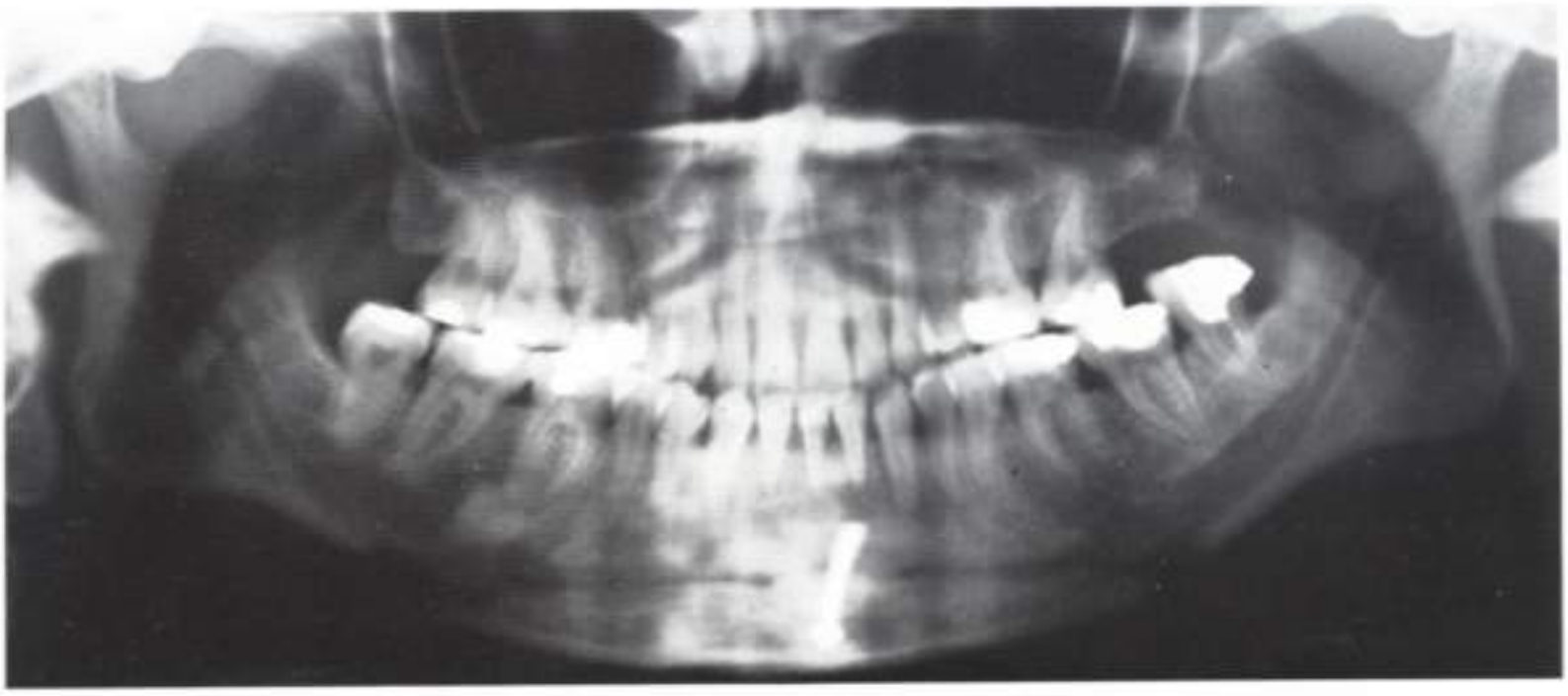
Panoramic radiograph at the end of the active treatment stage prior to extraction of the lower left third molar



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Lateral cephalograms at the end of active treatment and after genioplasty.

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Frontal and profile facial photographs after genioplasty